Water Scarcity and Water Policy in Mexico

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Gianluca Facchini

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Dedication

I dedicate this work to my family, for the unconditional love they gave to me and the unceasing moral support over these two years of studying, and to Mariana, my girlfriend.

Gianluca Facchini

April, 2009

List of abbreviations

CEHI:	Caribbean Environmental Health Institute
CNA:	Conagua, Comision Nacional del Agua
CONAPO:	Consejo Nacional de Poblacion
GDP:	Gross Domestic Product
DF:	Districto Federal
ED:	Electrodialysis
EEA:	European Environmental Agency
FAO:	Food and Agriculture Organization
FCE:	Comision Federal de Electricidad
HDI:	Human Development Index
IDA:	International Desalination Association
IMF:	International Monetary Fund
INE:	National Institute of Ecology
INEGI:	Instituto Nacional de Estadistica y Geografia
IRWR:	Internal Renewable Water Resources
LAN:	National Water Law
MSF:	Multi-stage flash evaporation
NF:	Nano filtration
PEMEX:	Petroleos Mexicanos
PIB:	Producto Interno Bruto (GDP in English)
REPDA:	Registro Publico de Derechos del Agua
RO:	Reverse Osmosis
SAGARPA:	Secreteria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion
SECTUR:	Secretaria de Turismo
SEMARNAT:	Secretaria de medio ambiente y recursos naturales
SMN:	Servicio Meteorologico Nacional
UN:	United Nations
UNAM:	Universidad Nacional Autonoma de Mexico
UNESCO:	United Nations Educational, Scientific and Cultural Organization
USA:	United States of America
VC:	Vapor compression
WRAP:	Water Right Adjustment Program
WUA:	Water user association
ZMCM:	Zona Metropolitana de la Ciudad de Mexico

List of figures

List of tables

Table of contents

INTRODUCTION

Everyone knows industry needs oil. Now people are worrying about water, too - “The Economist” (august, 2008).

The most basic of all natural resources, although sometimes taken for granted, is water. Recently, two hundred scientists in 50 countries have identified water shortage as one of the most worrying problems for the new millennium (the other was being climate change). Not surprisingly water has been described by the same scientists as “the oil of the twenty-first century”, or “blue oil”. Since 1950, global water use has more than tripled and on current trends, over the next 20 years humans will use 40% more water than they currently do now. The water problem is a global problem and it is strictly connected with the well-known growing global population. According to the UN, approximately three billion of people will face water problems by 2025, and half of the entire global population, almost four billion, will not have sufficient drinking water. In particular, the number of people living in water-stressed countries is projected to climb from the current 470 million to 3 billion by 2025. Most of those people mentioned above live in developing countries. To achieve these targets for freshwater provision in 2015, water supplies will have to increase especially for those people living in Africa, Asia, Latin America and the Caribbean part. For example, India and China are the most watched players, facing the toughest challenge to control an emerging middle-class that hankers for the current and projected water-intensive life enjoyed by people in the west. Furthermore, the poorest continent of the world in terms of annual freshwater renewal, is Africa, with its population expected to more than quadruple before converging to a stationary level by the end of the twenty first century. Of the 100% worldwide stock of water, 97% is salt water, 2% are glaciers, 1% is fresh water. Of this 1%, half is contaminated or consists of deep aquifers. Global consumption of water is divided as following: 70% is used in the agricultural sector, 20% in the industrial sector and only 10% for human consumption. Up to 50% of urban water and 60% of water used in agriculture is wasted through leaks and evaporation. Assume that a person drinks approximately 3.5 liters of water per day and an average of 3000 of litres is required to produce the food that this person consumes per day. If we assume that this trend increases, especially the consumption per capita, it is reasonable to consider that the supply of water, at least the clean and easily accessible are clearly under great pressure. What is controversial is that water problems are more related to mismanagement rather than scarcity. Sustainable development and poverty alleviation will only be achieved through better management of and investments in rivers, wetlands and the lands that drain into them. Mexico is a country facing this problem nationwide and not surprisingly water resource management is one of the most urgent environmental problems. Despite many accomplishments in the water sector, including a comprehensive legal system, a national water authority called CONAGUA (CNA) and a functioning water rights system, the country’s water sector is now facing significant challenges. The worse situation seems to rely on the continued over-exploitation of water resources, combined with a policy based on distorted prices and inefficient subsidies that discourage water allocation to its maximum productive uses. With water in Mexico becoming very scarce over time, it is now a factor that threatens to limit economic activity and social well-being in several regions. A careful analysis is therefore required by the mexican government to offset an ever-growing range of complications arising from the impact of different considerations, related to sustainability of water resources, fairness, pollution, environment, basic services, competition and globalization. Desalination can be a powerful and efficient solution in several regions of Mexico, especially for those cities close to the sea. After all, one of the most important sectors in Mexico's economy is tourism, a sector that needs fresh water all the year round, which is also provided by desalination plants. Nevertheless, Mexico's supply of fresh water does not meet the real growing food needs; this situation becomes even more critical if the recent population growth which has been occurred in the last two decades is considered. Still, the desalination market does not seem to develop as in other countries facing similar water scarcity problems. This thesis addresses the possible solutions to control demand and supply of water for a sustainable environment in Mexico, along with a detailed analyses of economic implications related to the water sector. At the same time it focuses on the opportunities and constraints to improve the use of water and the allocation in the agricultural sector, by a system of transferable water-use permits. Actual examples are provided nationwide to the current situation in Mexico, focusing on problems related to water scarcity, waste-water and water pollution, with emphasis on Mexico City. Finally, an overview of desalination technologies and their implications in Mexico will be described at the end of the thesis.

OBJECTIVES AND RESEARCH QUESTIONS

Identify the problems and possible solutions related to the water scarcity in Mexico

1- How should the Mexican government identify and tackle issues of water scarcity in the country ?
2- How should the Mexican government improve the national water policy, and what would be the benefits for the country ?
3- How would the agricultural sector benefit by reforming the subsidy system, in terms of demand/supply of water?
4- How should the Mexican government tackle the water scarcity in the Mexico City Metropolitan Area, taking into account the fragile equilibrium between growing population and environment aspects ?
5- How could desalination technologies become an effective solution to reduce water scarcity in Mexico, and what are the problems related to their application ?

CHAPTER 1

OVERVIEW OF THE MEXICAN ECONOMY: THE THREE SECTORS

1.1 Economic Index summary:

The mexican GDP has been subject of a fluctuating trend since 2000. The World Bank estimated in 2000 that the annual percentage growth rate of GDP (based on constant local currency) of 6.6%, and then in 2002 a percentage change of 0,82 which then increased to 5.1 in 2006. In 2007 the growth rate again decreased to 3.3% . The GDP per capita in 2000 (estimated at current prices in US dollars) was 6419 $ (US dollars) and in 2007 was approximately 9741 $ (US dollars). The inflation rate has been maintained in the last two years at 4%, much lower compared to the previous decade. To indicate this sharp decreased, the inflation rate (based on national price index) in 1995 was in fact 51.97%, then it significantly decreased and at the beginning of the twenty first century recorded as 8.96% (tab.1) In the same year, INEGI and CONAGUA have estimated the costs associated with improving the supply of the natural resources and reversing the environmental damages caused, both resulting from human economic activities. These costs are estimated to amount to a share of 9.2 % of the GDP.

The mexican economy can be divided in three main parts, according to the most relevant in terms of contribution to GDP: First, the industrial sector, which includes the energy sector (manufacturing, mining,construction,electricity, water and gas) has been estimated to contributing of the total GDP of 25%, in 2007. Second, the Services sector (including wholesale and retail trade, the tourism sector, transport and government financial, professional and personal services such as education, health care and real estate services) have been estimated as 71% on GDP. Third, the Agricultural sector (forestry, hunting, fishing and cultivation of crops and livestock production), estimated as having approximately 4% of the total GDP, in 2007.

However, I will analyse the most controversial and discussed sectors in the mexican economy; the energy sector, the remittance and the tourist sector.

1.2 The Oil sector

The energy sector is the most relevant and includes several sub-sectors, where the most important is the oil sector. The company which monopolizes owning the oil-sector is PEMEX and its impact on the mexican economy is significant. First, it generates over 15% of the country`s export earnings on top of which the government is heavily reliant on those earnings, from tax`s revenues and direct payments from PEMEX which accounts for about 40% of total government revenue. In other words, any decline in production at PEMEX has a direct negative effect on the country`s overall fiscal balance. Mexico`s total energy consumption in 2005 consisted mostly of oil (59%), followed by natural gas (27%). However, oil production in the country has begun to decrease due to the decline of the giant Cantarell field. In 2006, Mexico was the sixth largest oil producer in the world with Proven Oil Reserves of 12.4 billion of barrels, producing an average of 3.7 thousand barrels per day, of which 88% made up of crude oil. The production then decreased to 3.2 thousand barrels per day in 2008. The Proven Oil Reserves have subsequently been updated in january 2009 as being 10.5 billion barrels. On the other hand, oil consumption increased from 2006 to 2008, due to the significant growth in the population. In 2006, oil consumption was 1.9 thousand barrels per day and in 2008 this amount increased to 2.1 thousand barrels per day. Other fuel types contribute significantly less to Mexico`s overall energy data. Nevertheless, natural gas is still the second largest fuel source of the Mexico`s energy sector. Mexico`s production has grown in recent years, following a steady decline during the late 1990s. During that time, natural gas consumption was driven mostly by the electricity sector, whose share of total natural gas consumption increased from 16% in 1997 to 33% in 2007. PEMEX itself is the single largest consumer of natural gas, representing around 40% of domestic consumption in 2007. On the other hand, Proven Natural Gas Reserves decreased significantly; from 14.6 trillion cubic feet (Tcf) in 2006 to 11.8 trillion cubic feet (Tcf) in 2008, mainly concentrated in the southern region of the country. However, the northern region is likely to be the center of future reserve growth and PEMEX has estimated these to contain almost ten times as much probable and possible natural gas reserves as the southern region. The doubled increase in consumption and production of natural gas reflects the strong dependence on imports from the United States, via both pipeline and liquefied natural gas (LNG) that have been increased since 2006. Production increased by 1.7 (Tcf) in 2006 to 1.98 (Tcf) in 2007, consumption also increased by 2 (Tcf) in 2006 to 2.4 (Tcf) in 2007. A brief introduction of the state-owned company PEMEX is useful to better explain this oil-sector decline: PEMEX is a highly profitable company and oil has been an important player for the development of the country for several decades. However, during the last government led by the president Vicente Fox, from 2004, a weak fiscal system led the company to be significanly unprofitable and registering a loss estimated of 1300 million dollars. According to some analists, this financial mismanagement of PEMEX resulted from the willingness to open the oil sector to the private financial capital market. Moreover, the fact that oil production has begun to decrease substantially at a constant rate over the last two decades, largely due to reduced production from the giant Cantarell field, makes Mexico significantly less rich of hydrocarbon resources. In the short run, PEMEX does not have the ability to reverse this reduction in its oil resources, which could even disappear within two or three decades if no new hydrocarbon resources are discovered. With the absence of giant oil fields and the increasing costs of exploration and extraction, Mexico cannot sustain the level of production it did some years ago. Furthermore, PEMEX has been trapped by two forces: Taxes and external pressures. The recent "Oil Reform"[1] pointed out two future options: PEMEX to be run as a national monopoly or to be privatized. This would change the structure of PEMEX, but it is an option that may benefit the country. This model would require strong and efficient regulation in order negative consequences of privatization, following examples of other oil companies.

Tab 1. Main economic indexes of Mexico, 2000-2007

Index	year				
	1995	2000	2005	2006	2007
GDP (annual % change)	-6,167	6.602	3.213	5.127	3.33
GDP (US dollars)	314.1	628.8	672,8	952,3	1025.4
GDP per capita (US dollars)	3446	6419	8235	9137	9741
Inflation rate (annual % change)	51.97 %	8.96 %	3.33 %	4.05 %	3.76 %

Source: IMF, international Monetary Fund, World Economic Outlook, annual report, april 2009.US

Source: Annual report 2007, Bank of Mexico, April 2008 - http://www.banxico.org.mx , Mexico 2008

Source: INEGI. Sistema de Cuentas Económicas y Ecológicas de México, 1999-2004

[1] The necessity for an Oil Reform has been carried out by the Mexican President Felipe Calderon, who requested that a proposal of an oil reform for the energy sector to be sent to the Senate of the Republic on April 2008. The main focus of the initiative was to contract specialized companies for the construction and management of an oil refinery in the Gulf of Mexico. This initiative would also improve the financial autonomy of PEMEX regarding its oil revenues. The proposal does not concern any changes in the National Constitution, which establishes the control of the State over the energy resources, it is focused only on secundary changes of the law.

1.3 The Remittance

What can be considered as the second source in the mexican economy is the “Remittance”, in mexican “Remesa”, attributed largely to money sent home by migrants, mainly residing in the USA. The “Remesa” represents the second largest financial inflow to the mexican economy. It contributes to economic growth but above all to the livelihoods of needy people. In Latin America and the Caribbean, remittances accounts for more than 10% of GDP and exceeds the dollar flows of the largest export product in almost every country in the region. Mexico is one of the most documented examples of migration and remittances, the third largest recipient in the world after India and China, with a share of GDP of 3.0% in 2007. The fact that this figure may appear relatively low compared to the agricultural sector (4%), Mexico recieved remittance inflows in 2007 of 26068.7 million dollars[2], 95% of which came from the USA, making this significantly relevant in terms of inflows. However, under the financial crisis this trend is decreasing. After all, as is often the case for migrants workers, many mexicans currently work in informal or illegal employment in the USA and are therefore at high risk of job losses during this crisis. According to INEGI (National Institute of Statistics and Geography) the total national inflow registred during the period between 2004 and 2008/2009 indicates a bell-shaped trend. In 2004, the total family income by remittance was 18.331 million dollars and from 2005 to 2007 this trend increased reaching the maximum figure of 26068.7 million dollars in 2007. However, in 2008 this trend slowly decreased, reaching 25137 million dollars. Mexico City, considered as the Federal District, faced a decreasing trend as well. The average family income by remittance decreased from 1524.6 in 2006, to 1374.8 in 2007 and to 1105.3 million dollars on 2008.

[2] The IFM (international monetary fund) has quite different result. 2007 has been registred with 27144 millions US dollars and 2008 with 26212.

1.4 The Tourism sector

The third sector analysed here is tourism. Historically, the tourism sector has represented around 8.6% of Mexico`s GDP: In 2003, the tourism contributed 8.8% of the total GDP, then this figure increased to 9.0% in 2004. Either in 2005 and 2006 it has been estimated as an average of 8.7% on GDP (INEGI,2006). In 2007, 92.2 million international visitors entered in Mexico; 21.4 million were international tourists (overnight visitors) and 70.8 million were same-day visitors, of which 6.8 million as cruise passengers (tab.2). The most important destinations in Mexico for international tourists are Cancun and Cozumel (22%), Guadalajara and Los Cabos (7%), Puerto Vallarta (6%), Mexico City (5%) and Acapulco (4%). The proximity to the USA is reflected by the fact that almost 70% of visitors come from there. According to SECTUR (Secretariat of Tourism, 2008), the period between 2000 and 2007 has been subject to fluctuations in terms of number of visitors. In 2007, 78.5% of the visitors passed the north-boarder while the rest 21.5% (19.8 million) were directed in the rest of country. By the 2001 the number of visitors decreased due to the effects of 9/11, especially from USA. This situation contined until 2003, which registered a decrease of 9.7 million of visitors. The foreign occupancy rates in Los Cabos (Baja California Peninsula) dropped as well to 9% in 2002. However, the occupancy rate in Baja California increased to 46% in 2006. Cities like Cancun and Cozumel, Acapulco, Playa del Carmen, which lie on the coastline need fresh water throughout the year, hence a continuing water source is required for the sake of the tourism business. In general, fresh water can be provided by two methods: by extracting groundwater and pumping it through pipes towards the users, or by desalination of the seawater by appropriate plants. In fact, the continuing over-exploitation of the aquifers was led to a nonprice and unregulated rationing, distorting growth in most dynamic economic regions, and an increase in negative environmental impacts as new wells are exploited. Nevertheless, only the USA/MEXICO boarder and the area of the Baja California Peninsula,which have very limited water resources with a problem of salinity, have taken seriously and carried out such desalination technologies during the last decade.

Tab.2 Tourist visitors in Mexico, 2007

year 2007	Number of visitors (million)
TOTAL VISITORS	**92,2**
International Tourists	21,4
Within border zone	8,4
Full-time tourist	13
Same-day visitors	70,8
Within border zone	63,9
Cruise Ships	6,8

Source: own elaboration based on SECTUR, (Secretariat of Tourism): “analysis of tourism”, 2008.

CHAPTER 2

STATISTICS OF WATER: WATER SCARCITY IN MEXICO

2.1 Demographic summary:

Mexico is a Federal Repubblic that consists of 31 states and a Federal District (DF), with 2438 city halls and 16 boroughs in the DF. Over the last fifty years, the population of Mexico has increased by more than four times, from 25.8 million inhabitants in 1950 to 103.48 million in 2005. The demographic growth rate for the period 1960-1970 was 3.4%, then slowly decreased reaching 1.02% in 2005.According to INEGI, the estimated growing rate for the period 2005-2010 will slowly increase to 1.1% nationwide, and 1.5% in urban areas. In 2007 the proportion of population living in urban areas was 77.0%, and the population density was 53 inhabitants for km^2, with Mexico City (including the federal district, DF) accounting for 22.8 million inhabitants. In 2005, Mexico accounted for 187.938 inhabited localities, where 24.28 million were living in rural areas and 79.20 living in urban areas. Approximately 10% of the rural population was spread out in small localities with less than 100 inhabitants, where the installation of water infrastructures is very expensive. The most inhabited regions are the metropolitan areas of Valley of Mexico, Guadalajara, Monterrey, Puebla-Tlaxcala and Toluca, where 30.8% of the total population is concentrated, meaning 31.81 million inhabitants.

Water Statistics Summary:

1- Average Precipitation in depth (mm/year) : 752
2- Average Precipitation in volume (km^3 / year) : 1471.98
3- Agricultural water withdrawal* (as % of total water withdrawal) : 77%
4- Public water withdrawal* (as % of total water withdrawal): 14%
5- Industrial water withdrawal* (as % of total water withdrawal): 9%
6- Surface Water: produced internally (km^3 / year) : 361
7- Groundwater: produces internally (km^3 / year) : 139
8- Overlap between surface water and groundwater* (km^3 / year) : 91.0
9- Water resources*: total internal renewable water resources (IRWR) (km^3 / year) : 409
10- Water resource*: total internal renewable water resources per capita (m^3 / year) : 3883
11- Natural Renewable water resources (km^3 / year) : 457
12- Natural Renewable water resources per capita* (m^3 / year) : 4340
13- Total water withdrawal per capita* (m^3 / inhab /year): 769
14- Aquifers exploited over the total number of aquifers: 104/653
15- Desalinated water produced* (km^3 / year) : 0.0307
16- Municipal wastewater : treaded volume (m^3 / sec) and in percentage: 74.4 = 36.1%
17- Municipal Wastewater: produced volume* (m^3 / sec): 242

Source: Statistics of water in Mexico,2007 edition. CONAGUA, National Water Commission

Source: FAO. Information System on Water and Agriculture, AQUASTAT.June 2007.For the case of Mexico

Notes:

3*,4*,5*: Sector share of water withdrawals, expressed as a percentage, this refers to the proportion of water used for one of three purposes: agriculture,industry and public uses. Evaporative loss from storage basins are not considered here. Agricultural uses of water primarily include irrigation and,to a lesser extent,livestock maintenance. Public uses include drinking water plus water withdrawn for homes,municipalities,commercial establishments and public services. Industrial uses include cooling machinery and equipment, energy production, cleaning and washing goods produced as ingredients in manufactured items and as a solvent.

8*: it is the volume of water resources common to both surface and groundwater. It is calculated by Surface water + groundwater - IRWR

9*,10* : Total internal renewable water resources as the sum of surface and groundwater resources minus overlap. Natural incoming flow originating outside a country`s borders are not included in the total. Per capita internal renewable water resources are measured in cubic meters per person per year. These values were calculated by using national population data for 2001.

12*: Natural renewable water resources per capita as the sum of internal renewable water resources and natural flow originating outside of the country. The values are also calculated in cubic meters per person per year. The data was provided by CONAGUA for 2006 is 4416 (fig.4). However, the latest data updated by Aquastat for 2007 is 4340 m^3 / inhab/ year.

13*: the total annual amount of water withdrawal per capita as the sum of the three sector`s total water withdrawal / total population. (AQUASTAT, 2002)

15*: Desalinated water produced: Water produced annually by desalination of brackish or salt water. It is an annual estimate based the total capacity of water desalination installations (year 2000)

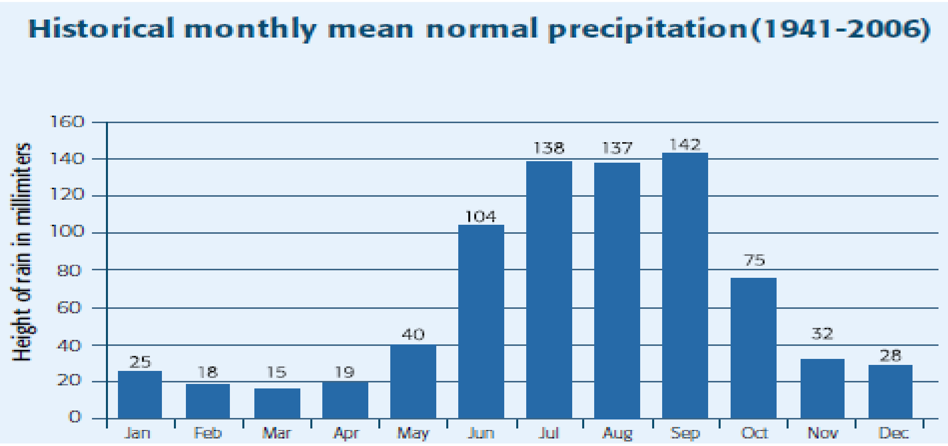
17*: The volume of wastewater produced: Annual quantity of wastewater generated in the country, in other words, the quantity of water that has been polluted by adding waste. The origin can be domestic use (used water from bathing, sanitary, cooking, etc.) or industrial wastewater routed to the wastewater treatment plant. It does not include agricultural drainage water, which is water withdrawn for agriculture but not consumed and returned to the system.

This data was updated in 2007, by the National Water Commission (CONAGUA).

2.2 Average precipitation

Water is a disproportionately distributed natural resource in Mexico. For example, while it is very scarce in the north-west part, in the Baja California Peninsula, which receives just 202 mm of rain-fall per year, the State of Tabasco in the south gets twelve times as much, almost 2410 mm per year. Almost 70% of the rain-fall is lost through evaporation and returns back into the atmosphere, the remaining 30% is absorbed by the grounwater aquifers and drains into rivers. In general, 67% of the rain occurs over just four months of the year, from June to September, a typical characteristic of tropical countries like Mexico (fig.1). This makes it hard to take advantage of it efficiently, thus it is necessary to build major infrastructures for collecting and storing it. It is important to understand that two-thirds of Mexico is arid or semi-arid (21% and 36% respectively), which necessitates the efficient use of water in all activities, ranging from irrigation to industry and public uses.

Fig.1 Historical monthly mean normal precipitation (1941-2006)



Source: Statistics on water in Mexico, 2007 edition. CONAGUA

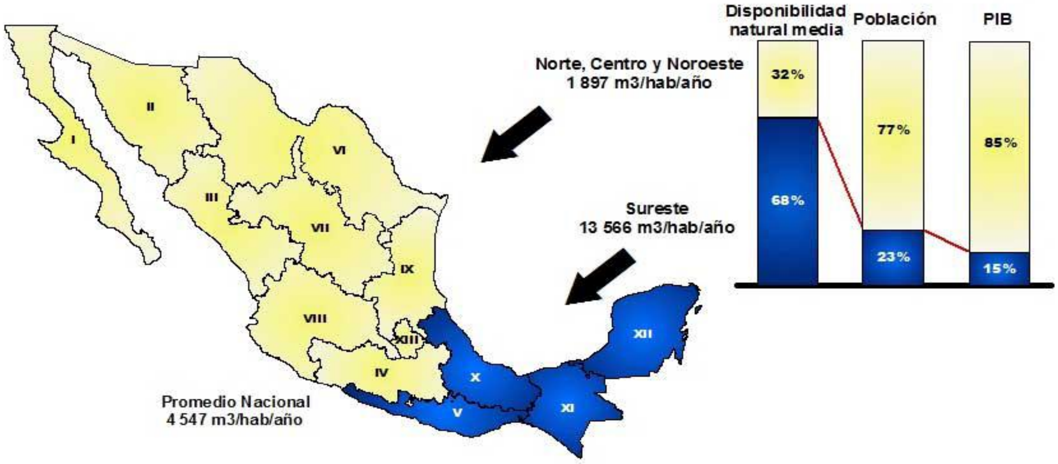
2.3 Distribution of water in the country

Figure No.2 shows the availability of water relative to economic activity in Mexico in terms of GDP[3]. It should be clear that the population density and the economic activity are in inverse proportion to the availability of water in the country. Mexico has two wide areas with water availability: the south-east and the north, centre and north-east, and is divided in thirteen hydrological-administrative areas (tab.3 and fig.3). The natural availability on the south-east part is seven times higher than in the rest of the country. The rapid urban and industrial growth experienced since the 1940`s, together with the creation of important irrigation zones are factors that have contributed to the increased demand for water in the country. On a national level, the greatest population and economic growth have taken place in areas with less water availability. 77% of the population is concentrated in the north, centre

[3] Fig.2 shows the average natural renewable water resources per capita of 4547 m^3 / year, based on year 2003. (CONAGUA)

and north-east part of the country, generating 85% of the total GDP (PIB in spanish). However, these regions are characterized only by an average of 32% of the total yearly precipitation, hence several economic constraints are imposed to agricultural and irrigation activity, performing 92% of total irrigation activity in the country. This situation is in sharp contrast with the southeastern part of Mexico, with 68% of water availability and only 23% of the country`s inhabitants. In addition, more than 25% of Mexico`s population lives in areas of over 2.000 meters above the sea level and receive only 4% of the water volume of the rivers, whereas the comparably-sized population that lives on areas less than 500 meters above the sea level receives more than 50%.

Fig.2. Distribution of water in the country in proportion to the population and the GDP (PIB in spanish)



Source: Statistics of Water in Mexico,2003-2007 edition. CONAGUA

2.4 Water uses

With regards to water uses, the volume of water granted in the form of concessions up until to December 2006, not including the generation of hydroelectric power, was 77.321 billion cubic meters. Of that, 77% was for agricultural uses, 14% for public use, 9% for industries that obtain water from rivers and aquifers. The volume of water granted in concessions until 2006 for hydroelectric power generation was 158.566 billion cubic meters. Of these figures, during that year 140.295 were utilized to generate 13.2% of the country`s electrical power. The utilization of water seems to be still very inefficient; in the agricultural sector fluctuating between 33% and 55%, while in the cities it ranges from 50% to 70%. It is also important to consider that in different metropolitan areas of the country, water supplies sources and hydraulic infrastructure, are insufficient to meet the population`s needs. This situation has increased the social and political conflict resulting from the use of water and has also generated an unequal scarcity of water that has had a major effect on the most vulnerable of the population. An example of this is Valley of Mexico, whose sewage system is especially vulnerable during the rainy season (see chapter 5 for further details about Mexico City).

Tab.3 Hydrological and Administrative areas

HYDROLOGICAL AND ADMINISTRATIVE AREAS		
AREA		CITY HEADQUARTERS
I	Baja California Peninsula	Mexicali, Baja California
II	North-west	Hermosillo,Sonora
III	Northern Pacific	Culiacan,Sinaloa
IV	Balsas	Cuernavaca,Moreles
V	Southern Pacific	Oaxaca,Oaxaca
VI	Rio Bravo	Monterrey,Nuevo Leon
VII	Central Basins of the North	Torreon,Coahuila de Zaragoza
VIII	Lerma-Santiago-Pacific	Guadalajara,Jalisco
IX	Northern Gulf	Ciudad Victoria,Tamaulipas
X	Central Gulf	Xalapa,Veracruz
XI	Southern Border	Tuxtla Gutierrez,Chiapas
XII	Yucatan Peninsula	Merida,Yucatan
XIII	Waters of Valley of Mexico	Mexico,Districto Federal

Source: internal regulation of CONAGUA, Mexico 2006

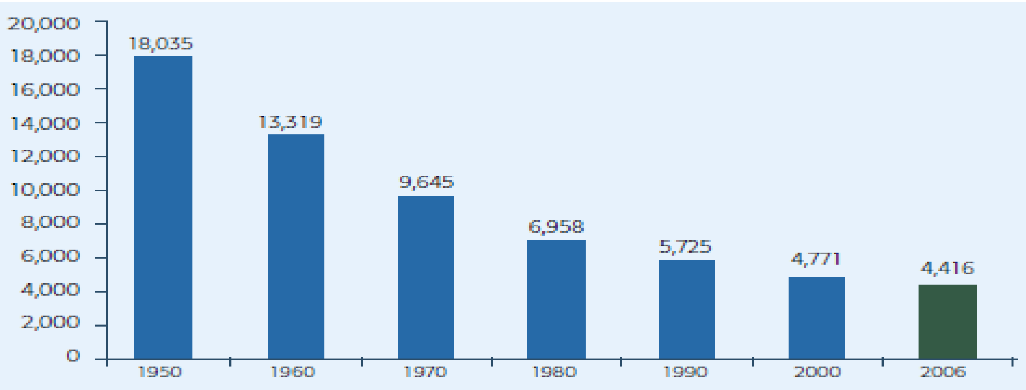
Fig.3 Hydrological-Administrative regions of Mexico

Source: Statistics of Water in Mexico,2007 edition. CONAGUA

2.5 Water availability per capita

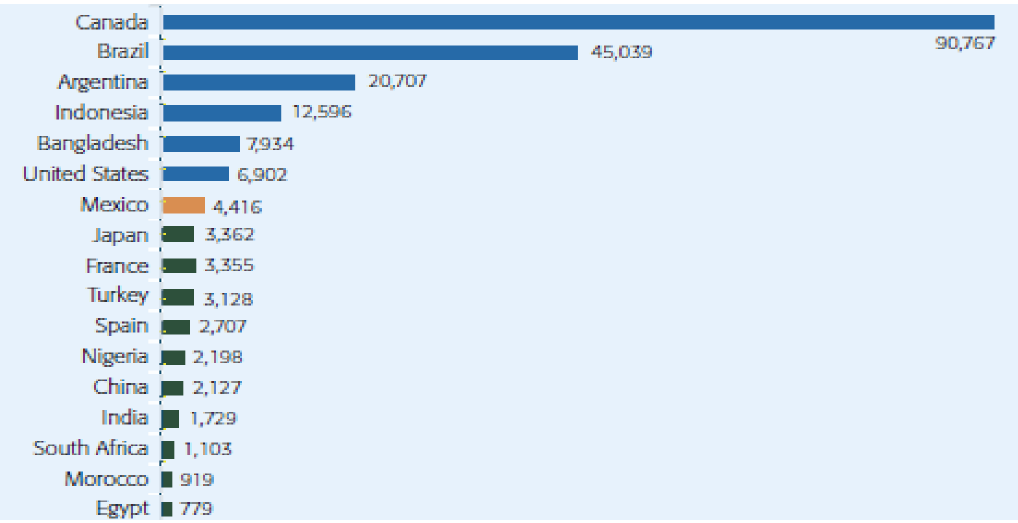
One reference parameter used throughout the world with regard to water is per capita availability. In just 56 years, Mexico went from an availability of 18.035 m^3 per inhabitant per year to 4.416 (2006) then decreased further to 4.340 in 2007, which places it in a delicate situation (fig. 4 and 5). In 2006, over 77.3 billion m^3 was consumed in Mexico, of which 10.7 billion m^3 was used for domestic consumption. The per-capita water supply estimated in 1995 was 364 liters/day in Mexico City and 230 liters/day/capita in the state of Mexico, which represents a total average daily consumption of 297 liters/day/capita.

Fig.4 Water uses in Mexico. Evolution of water availability in Mexico (m^3 /inhab/year)



Source: Statistics on water in Mexico, 2007 edition. CONAGUA

Fig.5 Average availability in different countries (m^3 /inhab/year)



Source: FAO. Information System on water and Agriculture, AQUASTAT.June,2007. For the case of Mexico,CONAGUA

2.6 Risks related to meteorological events

Given Mexico`s geographical location, it is periodically subject to hurricanes and droughts that cause serious damage in large portions of the territory. In addition, it is expected these will be even more frequent and intense due to the effects associated with climate change (tab. 4). The damages associated with hurricanes are increasingly more serious due to the location of irregular human settlements in areas close to rivers, the lack of enforcement of land use regulations and deforestation. Insofar as the positive effects of the hurricanes are concerned, these help to increase water stored in dams and lakes, which in turn is reflected in greater water availability for cities, irrigation, and electric power generation. Similarly, these favor the refill of aquifers by improving the ecosystem. However, in contrast, hurricanes can also cause different types of damage to the population, infrastructures, services and production systems. The first thing the government does in such situations is to send fresh water to the affected areas. Experience has shown that to mitigate possible damage associated with these events, the authorities should work mainly by taking preventive actions. For that reason, Mexico is installing early warning systems for its inhabitants, thanks to the Mexican National Meteorological Service (SMN) that allows it to generate more frequent and accurate forecasts of the weather, climate, and such meteorological events. However, as part of these preventative actions, desalination technology should be considered more as most rapid alternative to provide fresh water to the affected area. Where droughts are concerned, these occur every year in different parts on the country. Their duration may vary; the zones most affected by droughts are in the north due to the proximity to the hemisphere`s desert belt. Droughts drastically reduce the volume of water stored in dams and also diminish aquifer recharge, jeopardizing drinking water supply and affecting the most important sectors; agriculture and industry. For this reason, it is also essential to have contingency plans including preventive and mitigations actions for these natural catastrophes.

Tab.4 Hurricanes in Mexico, 1980 -2006

Hurricanes that have hit Mexico (1980-2006)		
ZONE	**NUMBER**	**CATEGORY (3 to 5)** winds over 180 km/h
Pacific	33	5
Atlantic	14	6
TOTAL	47	11

Source: Statistics on water in Mexico, 2007 edition. CONAGUA

2.7 Basins and Aquifers: Solutions for the water scarcity

In Mexico, water is considered a strategic and essential element of national security. In order to control water scarcity occurring in the country, the National Water Commission is carrying out a plan at different levels. At a national level, major policies and strategies associated with water management and conservation are proposed; at regional level, implementation is defined in more detail, considering the characteristics of each particular zone in the country. At a local level, policies and strategies are applied so as to have a favorable impact on social well-being, economic development and environmental conservation. In order to ensure the continuity of actions agreed upon jointly by users and officials, it is indispensable that the water programs drawn up for the different river basins be defined by law as mandatory. A situation that Mexico should improve is the preservation of ground-waters, e.g. basins and aquifers. The total annual extraction of underground water is approximately 27.5 km^3 per year, of which 71% is for agricultural use and 20% for public-urban use. In the past 40 years, since 1975, the number of over-exploited aquifers has increased substantially

(tab.5). The strategic groundwater reserves have lost almost 60000 hm^3 and continue to diminish at a rate of 5.400 hm^3 per year. To this day 104 over-exploited aquifers exist, meaning that the extraction is higher than the refill level (at least 10% higher). The majority of these aquifers are located predominantly in the centre, north-east part of the country. The figure below shows the actual reality: 32 in 1975, 36 in 1981, 80 in 1985, 97 in 2001,102 in 2003 and 104 in 2006. In addition, 17 aquifers are facing problems of saline intrusion (fig. 6). The colored spots indicate the over-exploited aquifers and the light-black spots those with salt-intrusion, mainly located close to the seaside. In particular, the regions with higher demand are those in the centre part of the country, e.g. the hydrological areas VIII and XIII. Mexico City is located in the latter. Both regions extract 47% of the total urban groundwater. The early decades of over-exploitation led to a serious ecological impact, generating depletion of springs, the disappearance of lakes and wetlands, a reduction of the basic flow rate of rivers, the elimination of native vegetation and loss of ecosystems, and groundwater pollution, including saline intrusion in coastal aquifers. The greatest problems are found in 17 aquifers in the states of the Baja California, Baja California Sur, Colima, Sonora and Veracruz. The problems related to over-exploitation might be considered as the most urgent for Mexico. Groundwater quality is in effect becoming a limiting factor for availability. There are polluted aquifers underlying agricultural and urban-industrial zones, while rural zones have caused the biological pollution of groundwater. At the same time, some aquifers have involved the public health system, because these contain chemical elements such as arsenic, fluorine, iron, and manganese derived from rocks and dissolved in the water in concentrations above those defined as permissible.

The mexican government along with the National Water Commission has recently published the following plan (National Water Program 2007-2012), in order to pursue real actions for the sake of a sustainable environment.

Here below list the main points:

1- promoting geo-hydrological exploration searching for new sources.
2- observation of the behavior of water levels in aquifers, as part of integrated monitoring of the water cycle.
3- Measurement of withdrawals and natural discharges of aquifers.
4- Monitoring of natural quality of the aquifers and their deterioration caused by human activities.
5- Assessment of aquifers` features, renewal and water availability.

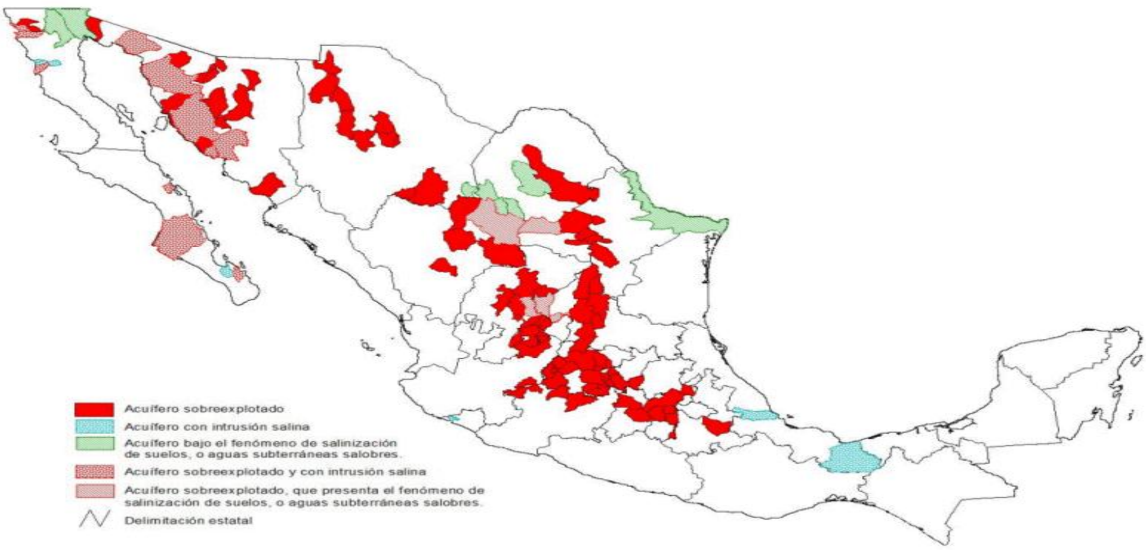
These actions should be framed within management plans following an inter-institutional approach with the establishment of the corresponding ordinances (prohibitions, regulations and reserves) agreed upon by the water user associations.

Tab.5 Number of over-exploited aquifers

YEAR	No. OF OVER-EXPLOITED AQUIFERS
1975	32
1985	80
2006	104

Source: Statistics on water in Mexico, 2007 edition. CONAGUA

Fig.6 Map of the over-exploited aquifers



Source: Statistics on water in Mexico, 2007 edition. CONAGUA

2.8 Superficial waters: Rivers and lakes

Mexico has a large number of lakes and rivers. Of Mexico`s 39 most important rivers, 22 are feed into the Pacific, 14 into the Gulf of Mexico and 3 are inland rivers (fig. 7). The Chapala lake is the largest in the country which is not very deep (4 to 6 meters). The Lerma river supports the lake with an average of 273 ha^3 per year, although over 1300 ha^3 evaporates each year. The water flowing into rivers accounts for 399 Km^3 per year, including the affluent inflow from neighbouring countries and excludes those flowing out. Seven rivers are responsible for 65% of the country`s surface runoff: Balsas, Santiago, Grijalva-Usumacinta, Papaloapan, Coatzacoalcos, Panuco and Tonala. Approximately 87% of this runoff is located in the 39 main rivers, whose basins represent 58% of the total territorial extension of the country.

Fig.7 Superficial waters

Source: Statistics on water in Mexico, 2007 edition. CONAGUA

CHAPTER 3

THE IMPACT OF WATER IN THE AGRICULTURE SECTOR

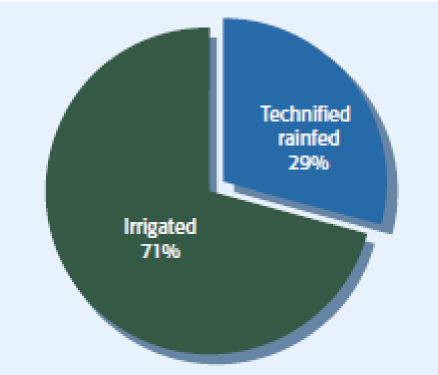
3.1 Statistics of water in the agriculture sector

The agriculture sector is the one that requires the highest amount of water for irrigation and the respective area covers approximately 21 million hectares (10.5% of the country`s territory), of which 6.5 million hecaters are irrigated and 14.5 hecaters are rain-fed. In 2003, the agricultural sector contributed 3.8% to the total GDP figure. However, this percentage has decreased since 2003 and in 2006 was estimated to be 3.2%[4] The population living in this area is about 4.5 million people, but almost 20 million of Mexicans are dependent on these activities, most of which are those in the rural areas. The productivity of the irrigation-area activity is,on average, 3.7 times greater than the rain-fed ones, despite the fact that irrigated areas account for a substantially smaller surface area and irrigated farming alone generates more than half of the national agricultural production. Mexico occupies the sixth place in the world for irrigation infrastructures, with 6.46 million hectares, behind China, United States and India. Over these 6.5 million hectares under irrigation, 3.5 million (54%) are in 85 irrigation districts, 82 of which have already been transferred to users, and 3.0 million (46%) are in 39.492 irrigation districts. With regads to rain-fed areas, 2.7 of the total 14.5 million hectares are located in 22 Technified Rain-fed Districts. Originally, the districts and the irrigation fields were designed according to current technology to benefit most vulnerable areas. Unfortunately, a lack of proper control by the authorities together with period of financial scarcity, led to an inefficient management of the water. Over the total volume of water utilized in irrigation districts, 88% comes from surface sources, and it is stored in dams or diverted from rivers, while the remaining 12% comes from groundwater sources, extracted from aquifers through deep wells. For irrigation districts, 57% of the water used here is groundwater, while 43% is surface water; both in the irrigation districts and units. The water is then transported to the plots by several canals and pipes (fig.8). It is important to note that 77% of the water utilized in Mexico is aimed at agriculture and that water availability is scarce in large areas of the country, as well as the fact that water use efficiencies in irrigation are, for the most part, rather low. The situation becomes even more critical if we consider that Mexico`s recent population growth is putting increased pressure on agricultural production in order to meet growing food needs. To solve this problem, CONAGUA is moving in several directions considering different alternatives. The modernization of irrigation technology will make it possible for them to increase the productivity of water by 2.8% per year (measured in kilograms per cubic meters of water used in irrigation

[4] INEGI, National Institute of Statistics and Geography, august, 2008. According to the World Bank Group, the value added as percentage of GDP estimated from 2000 to 2007 has been approximated to 4%. Source: World development Indicators Database, September 2008.

districts, Kg/m^3), which is projected to cause an increase of 1.41% in 2006 to 1.66% in 2012. This is hoped will lead to a greater benefits for producers, who will be able to control the supply of water, while at the same time it will be possible to achieve more efficient water use by substantially reducing the consumption, e.g. the demand of users.

Fig.8 Comparison between the land surface of irrigation and technified rain-fed districts



Source: Statistics on water in Mexico, 2007 edition. CONAGUA

3.2 The value of water

In the irrigated agriculture segment of the economy, the Government of Mexico has implemented various programs to use water more efficiently, such as those for the efficient use of water, energy and ferti-irrigation. The modernization of such technologies will not be helpful just to control demand and supply of water, but will also be able to determine water savings and utilize the saved water for other priorities in river basins, as well as to promote the preservation of supply sources. In addition, the Water User Associations would be able to compensate those farmers affected by the negative externalities due to the reduction of water supply in several areas. In this regard, the government should introduce the concept of water as a productive input, measured in terms of its value added per volume. This would help to define the most approriate uses of this already scarce resource, optimizing its application and extending the vision towards the industrial and the service sectors, such as tourism. By reducing the volume of water used in irrigation as a result of such innovations, the rights of concessions would be better adjusted based on water availability. In effect, despite improvements made in water policy, problems still remain including excessive granting of concessions and seriously over-exploited aquifers. Finally, given the extreme scarcity of water in vast areas of Mexico, it is indispensable to foster reconservation towards crops that are more profitable and consume less water, taking into account water availability and soil suitability.

3.3 Major Infrastructure

Major infrastructure in Mexico accounts for approximately 2.200 storage dams that supply water to irrigation districts and units, of which some 35% are more than 40 years old, while their useful "design-life" would be 50 years. For this reason, an extensive program aimed at rehabilitating and conserving these works and their structures has been planned by the Government, together with the National Water Commission, in order to provide security to the populations living close to these infrastructures, and to guarantee granting of the volumes required for the urban, agricultural and industrial sectors. In Mexico, there are places with available water which are suitable for agriculture, nevertheless these places aren currently not maximized in terms of full-capacity uses. Therefore, it will be necessary to build infrastructure allowing for an extension of the surface devoted to irrigated and technified rain-fed agriculture,in order to obtain greater benefit from these land areas in harmony with the environment. The difficulty to apply this plan is to avoid possible social conflicts in the future among the different users who benefit from these infrastructural improvements. Regulation for using it and for distributing its water should be established, users should also be incorporated more into civil associations and "trained" in operating and conserving the infrasructure that is be granted to them in the form of concessions. (further details about water user associations in chapter 4).

3.4 Wastewater in Mexico: volume produced, treated and re-used

Index summary:

Wastewater produced volume: Annual quantity of wastewater generated in the country, in other words, the quantity of water that has been polluted by adding waste. The origin can be domestic use (used water from bathing, sanitary, cooking, etc.) or industrial wastewater routed to the wastewater treatment plant. It does not include agricultural drainage water, which is the water withdrawn for agriculture, but not consumed and returned to the system.

Wastewater treated volume: Quantity of generated wastewater that is treated in a given year and discharged form treatment plants. Wastewater treatment is the process to render wastewater fit to meet applicable environmental standards for discharge. Three broad phases of traditional treatment can be distinguished: primary, secondary and tertiary treatment. Discharge standards vary significantly from country to country, and therefore so do the phases of treatment. For purposes of calculating the total amount of treated waste water, volumes and loads reported are shown only under the "highest" type of treatment to which it was subjected.

Wastewater re-used volume: Quantity of treated wastewater which is reused in a given year. Wastewater treatment is the process to render wastewater fit to meet applicable environmental standards for recycling or reuse.

The disorderly growth of some cities, whose needs cannot be met by the sources of water supply currently available, is a significant constraint for the authorities, that can barely satisfy the balance of demand/supply of fresh water. For this reason, it is indispensable for municipalities to have reliable land-use plans based on water availability and to guarantee compliance with those plans. Same plans should regulate the sustainable growth of real estate projects and consider, when necessary, the recognition of water reserves when this is deemed appropriate for ensuring water supplies to major urban centers.

With regards to wastewater in Mexico, the Government, supported by the National Water Commission, has planned by 2012, the improvement techniques which treat wastewater through encouraging a better re-use of water. The quantity of waste water generated by the urban and industrial centers has increased as a result of changes in the consumption patterns and the adoption of new technologies. This has also increased the quantity of polluted waste flow, without previous treatment, to the rivers, lakes, aquifers and seas. In addition, the increasing presence of contaminated organisms partially hinders the exploitation of several rivers: According to CONAGUA, only 25% of the total superficial water is considered to not be contaminated; 50% considered slightly contaminated, 15% contaminated and 5% highly contaminated. The remaining part contains toxic organisms.
In addition, it is also necessary to intensify actions aimed to enhance physical efficiency in water distribution, since there are still serious losses due to leaks in supply networks, ranging from 30% to 50%, at national level. Information surrounding the real costs related to the wastewater should be made more public transparent, so the population would be more aware of this loss, above all in Mexico City where the situation is also significantly dramatic. In effect, the water which is wasted in both supply networks and homes is extremely expensive, since it has to be withdrawn from supply sources, purified via treatment techniques, stored, and transported by complex and costly infrastructures in order to reach industries and homes. In recent years, important progress has been made; the percentage of wastewater treated rose from 23% (16.8 $m^3/\sec$) to 36.1% (74.4 $m^3/\sec$) in 2006, and the National Water Commission is planning to increase this to 23.9% by 2012, with a cumulative goal of 60% (as % of the flow collected in sewage networks), equal to 123.6 $m^3/\sec$. On the other hand, the amount of wastewater produced has decreased significantly in 6 years, from 422 $m^3/\sec$ in 2000 to 242 $m^3/\sec$ in 2006 (tab. 6 and 7). Moreover, it is necessary to insist on the need for ensuring re-use of the water produced, which can help to cover part of the operating costs of water utilities, for example, by selling water to industry. Finally, a special effort will have to be made

by the authorities to reactivate those plants that are no longer operating or operating at low efficiency rates. As a matter of evidence, CONAGUA has planned by 2012 to increase the overall average efficiency by a further 8% for 80 water utilities in localities with more than 20.000 inhabitants. The last value, recorded in 2006, was 36.2% (as average efficiency) and the goal for the period 2007-2012 is 44.2%

Tab.6 Wastewater produced, treated and reused, 1995-2012

MUNICIPAL WASTEWATER	**year**	**1995**	**2000**	**2006**	**2012**
wastewater produced	$m^3/\sec$	298	422	242	na
wastewater collected in sewage networks	$m^3/\sec$	na	na	206	na
wastewater treated	$m^3/\sec$	16.8	82.5	74.4	123.6

Source: statistics on water in Mexico, 2007 edition. CONAGUA

Fao. Information System on Water and Agriculture,AQUASTAT.June 2007.For the case of Mexico

Tab.7 Wastewater produced, treated and reused, 2007

MUNICIPAL WASTEWATER	**UNIT OF MEASUREMENT**		**2007**	
wastewater produced	cubic km/year	cubic m/year	7.66	243
wastewater collected in sewage networks	cubic km/year	cubic m/year	6.53	207
wastewater treated	cubic km/year	cubic m/year	2.5	79.3
treated wastewater reused	million of tons of	BOD5 /year	2.07	na
wastewater re-collected in sewage networks	million of tons of	BOD5 /year	1.76	na
wastewater removed to the treatment systems	million of tons of	BOD5 /year	0.53	na
INDUSTRIAL WASTEWATER	**UNIT OF MEASUREMENT**			
wastewater produced	cubic km/year	cubic m/year	5.98	188.7
wastewater treated	cubic km/year	cubic m/year	0.94	29.9
treated wastewater reused	million of tons of	BOD5 /year	6.95	na
wastewater removed to the treatment systems	million of tons of	BOD5 /year	1.1	na
(*)BOD5: biological oxygen demand				

Source: SEMARNAT,Secretary of the Environment and natural resources. CONAGUA.Statistics of water in Mexico, 2008.Mexico,D.F.,2008

(*) BOD5 measures the rate of oxygen uptake by micro-organisms in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark

(*) na : not available

3.5 The subsidy system

The primary goal of mexican agricultural policy over the past century has been to increase farmers' income, in order to attempt to improve a sector in which most of the very poor work. Since 1983, mexican agriculture experienced an evolution of wage and output. In the same year, a severe economic-wide contraction occurred in the country, and the agricultural output grew. On the other hand, while the rest of the country was experienced a recession in 1988-89, agriculture experienced a severe setback. During the first stabilization program (1983-85) the agricultural output and employment reacted better than the overall economy, and the real wages in agriculture fell less than the aggregate real wages. Better prices for agricultural goods and unusually favourable conditions may explain this performance. However, during 1986, this situation reversed and agricultural output declined during the period 1987 to 1989, worse than that of the economy as a whole. The poorest were most affected, suffering a deterioration of their living standards[5]. The Government of Mexico has since the 1900s implemented several programs to use water more efficiently to promote this sector, especially for irrigated agriculture. Unfortunately, there are no precise indicators of the impact of such programs, although it is potentially negative because groundwater users benefiting from these programs have used water savings to provide a full supply when only a partial supply was previously available, or to expand their irrigated area and plant more than double the amount of crops. In short, whether agricultural subsidies actually benefits farmers, is an open "debate". One of the reasons is that there has not been sufficient integration among the various types of instruments used and among the authorities (CONAGUA, WUA's and REPDA)[6]. As a matter of fact, the electricity subsidy for agricultural irrigation pumping has been offset to a certain degree by the increase in the cost of extracting water that has contributed to the over-exploitation of aquifers.

As evidence, the figure No.9 shows the tariff's impact on energy consumption: electricity consumption decreased markedly during the two years in which the tariff 09 was increased (1990-92) , but when this tariff began to decrease, consumption rose again.

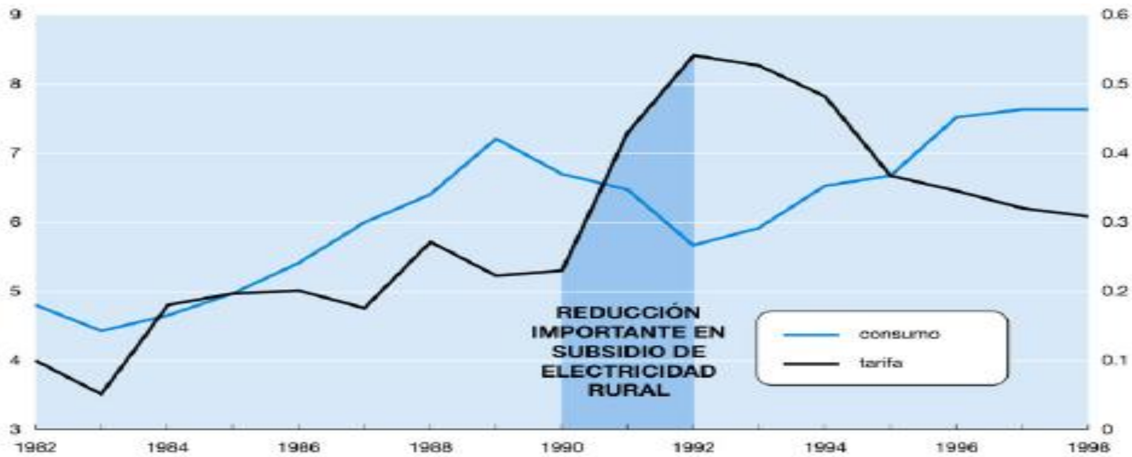
The irrigation fee increased by 400% in 1989-90 in order to prepare farmers for paying higher fees once O&M (operation and maintenance) responsabilities in terms of concessions were transferred to them. However, during the financial crisis of December 1994, which was followed by an annual inflation rate of 50% in 1995, the water user associations were not able to mantain the same fee level. The latest economic instrument that has had a notable effect on the reduction of groundwater extractions is the subsidy reduction on electricity tariffs for agricultural pumping. This paragraph is concentrated on this type of subsidy through a partial model that allows to estimate the elasticity of the

[5] see Friedmann, S., Lustig, N. and Legovini, A. (1995): "Mexico: Social Spending and Food Subsidies during adjustment in 1980s". Poverty and Inequality in Latin America, edition Lustig Nora.

[6] WUA: Water user associations . REPDA: Public Registry of Water rights of Mexico

water demand and the effects of this type of water policy in Mexico. The subsidy was implemented in 2003 by the mexican Government, aimed at those users whose activity was based on irrigation and agricultural activities. The government decided to support the farmers after their continuing concern and political pressure regarding the increase of competitiveness of the sector. On average, the cost to produce electricity in Mexico is 1.44 pesos/Kwh (0.14 US dollars). The tariff 9CU, aimed at those users having a concession for the use of the groundwater, is on average 0.33 pesos Kw/hour (0.033 US dollars). At the beginning the tariff was 0.30 pesos/Kwh, then in 2006 it increased to 0.36 per Kw/h. According to C.F.E[7], the amount of users in 2003 was 96164. Of these, 54499 had a water concession while 41665 did not have any (tab. 8). Overall, all the users recieved the annual subsidy for pumping equal to 1690 million pesos (169 million US dollars[8]). As in the United States with the agricultural subsidy system[9], same situation happens in Mexico with the tariff 09: the distribution is very unfair: on the one hand, more than 68000 users receive a subsidy of less than 20000 pesos per year (2000 $ US dollars) and on the other hand there are 33 users that receive a subsidy of more than 500000 pesos per year (50000 $ US dollars). The disparity takes into account the quantity of consumption of energy: those consuming more, get a higher subsidy (tab. 9).

Fig.9 Impact of energy consumption Tariff for groundwater pumping in Mexico



Source: CFE, Federal Commission of Electricity, electricity tariffs for agricultural pumping 2002 and 2003

The blue line (ending at 0.5 on the vertical axis) : Electricity consumption per year (Gwh/year)

The black line (ending at 0.3 on the vertical axis) : Electricity Tariff 09 (US dollars/Kwh)

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7 FCE: Federal Commission of Electricity, Mexico 2002

8 exchange rate estimated for the year 2002-2003 - 10 mexican peso = 1 US dollars

9 Barret, K. (2004): "The incidence of US Agricultural Subsidies on Farmland Rental Rates", Massachusetts Institute of Technology-Cornell University, November 2004, US.

Tab.8 Users and amount of subsidies of the Tariff 09

	number of Users	average subsidy per user ($/year)	total annual amount of the subsidy($ million)
Users with concession	54499	17787	969
users without concession	41665	17297	721
TOTAL	**96164**		**1960**

	number of Users	Number of users that recieve an annual subsidy more than the average value	Number of users that recieve an annual subsidy less than the average value
Users with concession	54499	16697	37802
users without concession	41665	10.965	30700
TOTAL	**96164**	**27662**	**68502**

Source : CFE Federal Commission of Electricity, electricity tariffs for agricultural pumping 2002 and 2003

Tab.9 Distribution of the subsidy among the users

	Number of Users without concession		Number of Users with concession		TOTAL	% of the total	
without subsidy	3739		4783		8522	9.10	
subsidy less than 50 $	7356		9535		16891	18	
subsidy between 50 and 100 $	2643		3659		6302	6.70	
subsidy between 100 and 500 $	7101		9623		16724	17.80	
subsidy between 500 and 1000 $	3770		5384		9154	9.70	
subsidy between 1000 and 2000 $	4382		6291		10673	11.40	
subsidy more than 2000 $	10881		14764		25645	27.30	
subsidy more than 50000 $	11		22		33	0.04	
TOTAL	39872	+	54039	=	93911		

Source : CFE, Federal Commission of Electricity, electricity tariffs for agricultural pumping 2002 and 2003

The table No. 10 indicates clearly the unequal distributed nature of the subsidy among the users. The Gini coefficient is a measure of statistical dispersion; defined as a ratio with value between 0 and 1. A low Gini coefficient indicates more equal distribution among the variables, while a high Gini coefficient indicates more unequal distribution. The Gini coefficient used for the tariff 09 and applied to the subsidy is 0.91, which defines a very unequal distribution of the subsidy.

Nevertheless, it has to be pointed out that the higher disparity lies in the fact that almost 70% of the farmers have temporary/seasonal jobs hence the they are not entitled to any subsidies. It is calculated as follow IG = $\sum(p_i - q_i)/\sum p_i$ (in percentage %)

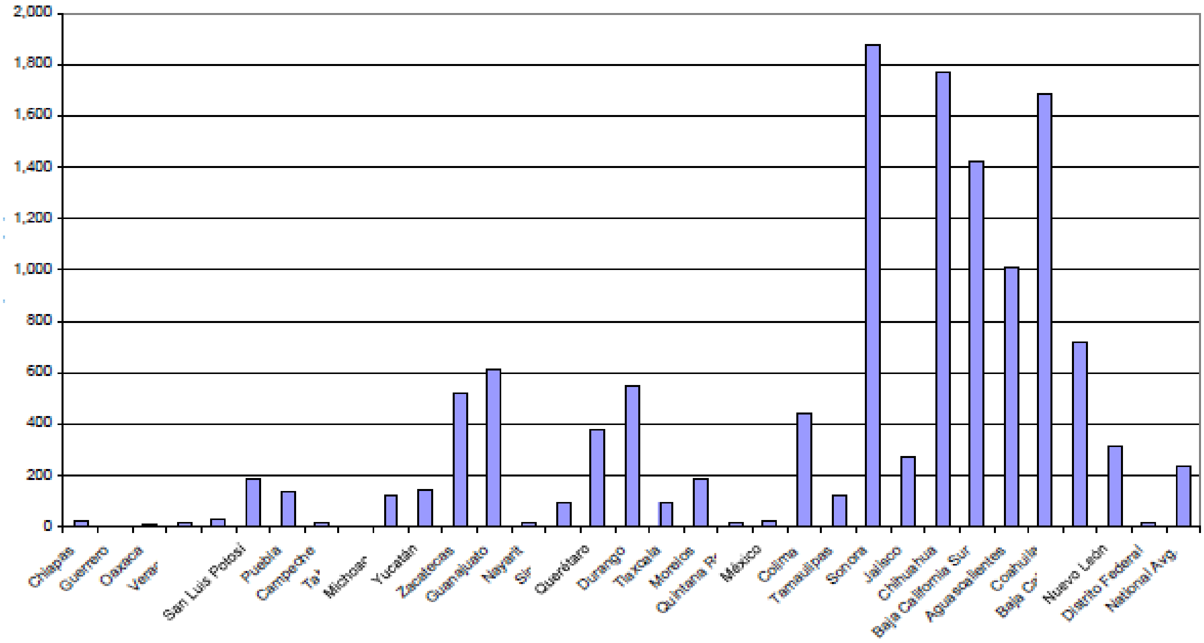
Tab.10 Distribution of the subsidy / Tariff 09 - GINI coefficient

Amount of the subsidy (mexican pesos)	Population accumulated (pi) (percentage %)	Subsidy accumulated (qi)(percentage %)
6666.7	59.9	2.41
13333.3	68.0	3.06
20000.0	73.9	3.76
26666.7	78.5	4.51
33333.3	82.2	5.25
40000.0	86.3	6.00
46666.7	87.8	6.71
53333.3	90.0	7.41
60000.0	91.7	8.03
66666.7	93.1	8.59
73333.3	94.2	9.08
80000.0	95.2	9.54
86666.7	95.9	9.95
93333.3	96.5	10.28
100000.0	97.0	10.58
5000000	100.0	100.0

Source: CFE, Federal Commission of Electricity, electricity tariffs for agricultural pumping 2002 and 2003

The figure No. 10 shows the clear disparity of energy subsidies among the mexican states in 2002. It is interesting to note that the state with the highest subsidy is Sonora (north of Mexico) where the W.R.A.P[10] aimed at recovering over-concessioned water volumes by means of economic incentives, was the first of these programs. The program was launched in 2003 by the minister of Agriculture[11]. The fact that a ministry of agriculture would lead a program with the objective of promoting the sustainability of productive systems as well as of river basins and aquifers is unusual at international level and represents a significant political willingness and a positive initiative for the sector by the mexican government.

Fig.10 Geographic distribution of the electricity subsidy in agriculture, 2002



Source: World Bank Report No. 27894-MX, Public Expenditure Review, pp. 86; 150-157

[10] WRAP: water right adjustment program, august 2003. Mexico
[11] SAGARPA: Ministry of Agriculture,Mexico

3.6 The model

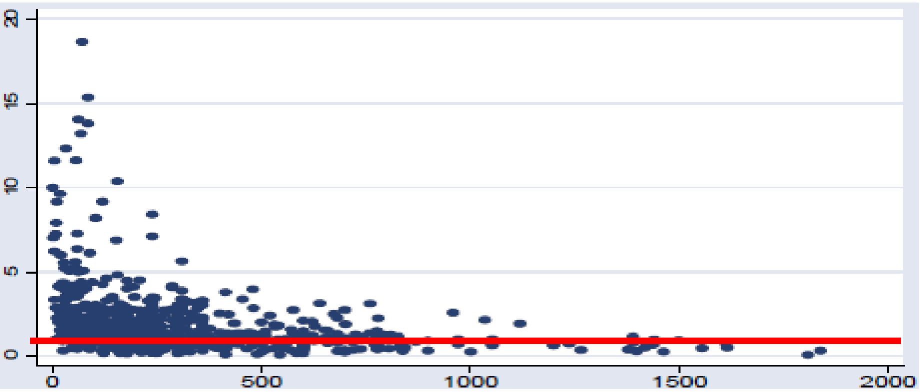
During 2002 and 2003, the Federal Commission of Electricity conducted a survey of over 1160 irrigation units. The results are summarized in the table No. 11 describing the "Student`s T-distribution", which shows that the total volume extracted (373) is statistically higher than the volume granted (267.2) with a negative difference of (-105.8). The interesting and most important result is that those users whose activity is irrigation consume more water than entitled to them by the authority through the concession, given that there is no relation between the volume which is granted and the total volume extracted. The relationship between extracted volume and granted is also illustrated in fig.11. This means that the concession itself is not a constraining variable to determine how much real water can be consumed. Perhaps the consequences of these methods might not be worthwhile, but under the sustainability point of view this is a serious problem the government should take into account.

Tab.11 T-student`s distribution between volume granted and volume extracted

Variable	Average	Standard error of the mean (SEM)	Standard deviation (SD)	Confidence interval 95% (CI)	
granted volume	267.2	13.2	450.2	241.2	293.1
extracted volume	373	12.5	424.4	348.5	397.5
Difference	-105.8	14.5	492	-134.3	-77.4

Source: CFE, Federal Commission of Electricity, electricity tariffs for agricultural pumping 2002 and 2003, based on a survey made by Colegio de Posgraduados, 2002-2003

Fig.11 Relationship between the volumes extracted and granted



Source: analysis of the subsidy to the tariff 09, DEEM-DGIPEA of INE, National Institute of Ecology. Program for the efficient use of water and of the electric energy.Mexico

The vertical axis : $V_{extracted} / V_{granted}$: Volume extracted / volume granted

The orizontal axis : volume granted

An interesting analyses is given by the following two linear models:

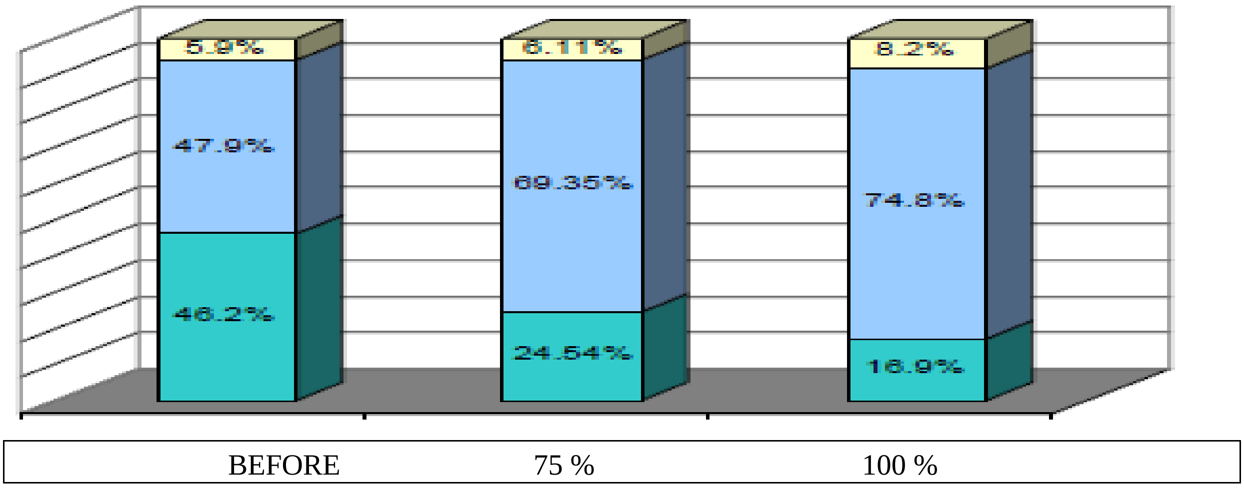
MODEL 1 (see Appendix, tab.12)

TVE (total volume extracted) = $\alpha + \beta_1$ Water Price + β_2 Temperature + β_3 Marginalization (1*)+ β_4 granted volume + β_5 Agricultural surface + β_6 users + β_7 Type Techn.1 + β_8 type techn.2 (2*)+ β_9 type of cultivation (fruit)+ β_{10} type of cultivaltion (vegatables) + β_{11} Fields + β_{12} Distance+ β_{13} Precipitation

(1*) index of marginalization = calculated by CONAPO, (National Council of Population, Mexico)
(2*) type of technology = two types of technology are used in irrigation activity. The type 1 is called "flood-irrigation", the type 2 is "dripping-irrigation"

This model allows us to observe the relationship between the different variables. TVE is the Total Volume Extracted, depending on several variables. According to the data , there is a clear and significant negative relation between water price and the dependent variable TVE (-1902.01). This can be explained by the fact that the extracting costs significantly change depending on the depth of the well. Temperature is not strictly correlated; its effect is minimized because there are most important variables, like the type of cultivation, the agricultural surface and the type of technology used. The relation between the Marginalization index and TVE is significantly negative (-38.17) which implies that one can expect higher water extraction in more developed cities and the closer the city is located to the place of extraction. In other words, the higher the index of marginalization, the less quantity of water is extracted. The agricultural surface is another important factor (4.98): the number of users is positively correlated with the volume extracted; the costs of finding an agreement among the users regarding the management of an aquifer increase as many users are involved. Another variable that indicate a positively correlated relationship is the type of technology used. The irrigation technologies are characterized by their efficiency. The most ineffective is the type1, the flood-irrigation, then the technology through sprinklers (sprinklers-type), then at last the type 2, the dripping-irrigation, considered the most effective (fig. 12). The graph below shows the distribution of the efficiency of the three different technologies before the increase of water-price of 75 % (second column) and 100% (third column). The bottom segment of the columns indicate the flood-irrigation type, the middle segment the sprinkler-type, and the upper segment the dripping-irrigation type. It can be seen that an increase in the water-price has a significant effect on the type of the technology used. In other words, an increase in the price of water, either directly or by an increase in the tariff 09 applied to the water price, will have an obvius direct effect on the demand and consumption of water. It also results, as can be seen from the graph, in an indirect change in the distribution of irrigation technology used. Thus, as fig.14 shows, by increasing the price of water by 100%, we can plot graphically the relevant proportional changes in which technology is used. It is important also to explain that this model does not specify the restrictions of land and liquid, but only describes the changes of probabilities of technology used. For example, with this model it is predicted that the producers of maize will use the sprinkler-type, which might not be true cause they barely use this type of irrigation during their activity[12]. The most significant changes are with type1 and sprinkler-type: the flood-irrigation type, considered the most inefficient, reduces its proportion by 29.3%, while the sprinkler-type, whose efficiency range is between 70 and 75%, increases its value by 27%. type 1, in effect, uses much more water than type 2, and the effect is absorbed in the variable "Dichotomic type 2" with a coefficient of 97.12[13]. However, there are no significant differences between the type 2 (dripping-technology) and the common irrigation method through sprinklers. The same can be seen with the type of cultivation method used: the intensity of the use of water in the fields compared with the requirement of water for grain-culture is so significant that minimizes the effect on the two types of cultivation (Fruits 0.092 and vegetables 0.010). Another variable that inficates significant results is the distance variable: as an index of access to the market for a city with at least 100000 inhabitants. The negative relationship (-0.29) can be explained as discussed previously by the index of marginalization.

Fig.12 Distribution of the irrigation technologies



Source: analysis of the subsidy to the tariff 09, DEEM-DGIPEA of INE, National Institute of Ecology. Program for the efficient use of water and of the electric energy.Mexico

[12] Guerrero Garcia Rojas, H. (2005): "Industrial Water Demand in Mexico: Econometric analysis and implications for water management policy". University of Toulouse 1, Social Sciences.

[13] dichotomic variable (binary search) is referred to "dichotomic search"; that is a search algorithm that operates by selecting between two distinct alternatives (dichotomies) at each step.

MODEL 2 (see Appendix, tab.13)

This similar model allows one to estimate the water-price elasticity of the demand.

Ln (total volume extracted) = $\alpha + \beta_1$ Ln (Water price + β_2 Temperature + β_3 Marginalization index + β_4 granted volume + β_5 Agricultural surface + β_6 users + β_7 type Techn.1 + β_8 type techn.2 (2*)+ β_9 type of cultivation (fruit)+ β_{10} type of cultivaltion (vegatables) + β_{11} Fields + β_{12} Distance+ β_{13} Precipitation

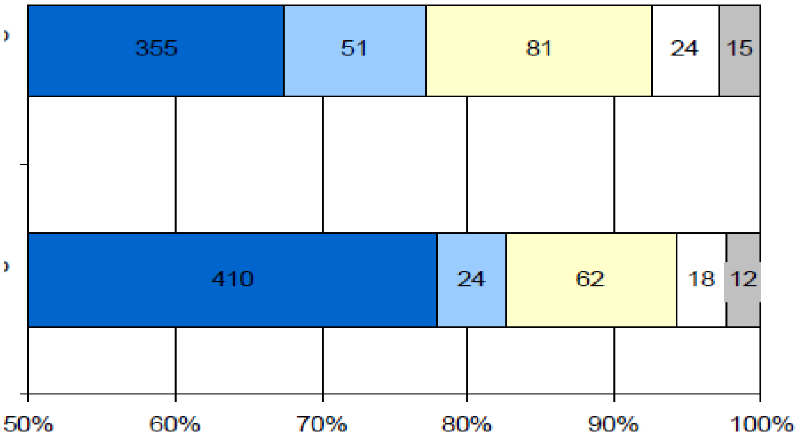
With this model it is possible to obtain a price-elasticity of -0.36 (-0.358). An increase in the price of electricity (Tariff 09) for pumping water leads to a reduction of the water demand. Again, Temperature is also not significant correlated with the volume extracted, and the same results as the previous model occur with the index of marginalization. The granted volume is also not significant, but the volume of water used increases with the number of users. Again, the effect of the dichotomic variable of flood-irrigation and of fields are also significant. Especially, the dichotomic variable of fields which eliminates the effects of other types of cultivation (0.092 fruit and 0.010 vegetables against the 0.187 of fields).

3.7 Conclusion

Consider the graph (Fig. 13)

1) The first row indicates the current subsidy that has been used in Mexico since the implemention, without the effects of subsidy decoupled to the tariff 09: effect on the aquifers
2) The second row is the proposed Subsidy analysed, decoupled to the tariff 09 : effect on the aquifers

Fig.13 Effects of the subsidy for the aquifers



Source: analysis of the subsidy to the tariff 09, DEEM-DGIPEA of INE, National Institute of Ecology. Program for the efficient use of water and of the electric energy, based on the Statistics of water of the National Water Commission of 2002, Mexico

The first quadrants of the rows from the left show the effects with a certain margin of extraction (355 and 410), in the second the effect is in equilibrium (51 and 24). From this, one can see that the extraction effect is alarming (81 and 62);extraction-level between 10 and 50% more than the refill-level, indicating that the extraction is heavy (24 and 18); extraction-levels between 50 and 100% more than the refill-levels. Finally extreme extraction (15 and 12); extraction-levels between 100 and 800% more than the refill-levels. An increase of 100% in the water-price is predicted by this model to have a direct and decreasing effect in the consumption of water by 35%. Decoupling the subsidy to a more efficient level might fits with the mexican situation which means that the Tariff 09 would have to increase from 0.30 to 0.63 pesos (0.06 US dollars) and indirectly affects the reduction of consumption of water as well by the same amount. In addition, better technology and more efficient agricultural production might reduce the total water consumption of 15%, to a figure of 2988 million liters less extracted from the aquifers. According to this data it can be observed that the price-elasticity of water consumption has significant effects over the exploitation of the aquifers: Less water demanded serves to therefore preserve the aquifers from over-exploiting. In other words, the necessity to decouple this type of subsidy with the tariff 09 would become a possible solution to control the demand and supply of water for the agricultural sector, but most important it would be fundamental for the sake of the environment, its preservation, development and sustainability with benefit for the country.

The increase in the price of the tariff 09 will bring the following results:

1) impact on the type of cultivation by reducing the water-use intensity on the fields
2) improvement of the irrigation technologies, by reducing the water and the energy consumption, in order to increase the efficiency and the productivity of the agricultural sector.

CHAPTER 4

THE WATER LAW AND THE SYSTEM OF WATER USER ASSOCIATION (WUAs)

4.1 History of the National Water Law (LAN)

Historically there is a clear difference between mexican property rights of water and concessions, initially introduced during the spanish period. The National Water law of 1992 (LAN) is the latest of a series of mexican water laws, starting with the Irrigation and Federal Water Law of 1926. During the last eighty years the water sector has improved significantly and in 1989 the National Water Commission, CONAGUA, (CNA), was founded as the only decentralized federal authority dealing with water management which holds water-property rights. The national water law (LAN) was finally approved in 1994 and represents the most relevant attempt to improve the management system around the water sector. In short, the reform was intended to stimulate economic growth through private investment in and capitalization of irrigated agriculture, which should eventually contribute to a more efficient and cost-effective use of the irrigation service. At an international level, many countries have introduced new water acts or modified existing laws to promote more efficient use of water. The most common methods are taxes, subsidies, tariffs and quotas. The effectiveness of these methods could lead to positive results which depend on the political and economic context in which they are applied. Given the index price as mirrors of scarcity, the water price has been utilized as the economic basic for an efficient and productive use of resources. Nevertheless, water has externalities, which implies that the private price does not reflect its social value. For example, water has an ecological and recreational function itself that are valuable for society. Furthermore, the water contamination caused by private users generates externalities. This scenario has to be reflected into the water price to gain the full picture and internalize the negative externalities. Unfortunately, this is not applied in Mexico and the water tariffs and commercial efficiency of the water authorities in Mexico are very low. In addition to Mexico`s incessant population growth and low water availability, the water in rivers and lakes has become insufficient in certain areas. Sources of groundwater supply are over-exploited and the natural quality of water has significantly deteriorated. This has brought on growing competition for water, leading to conflicts in different areas of Mexico. This situation is particularly critical in the rural areas where the state and federal subsidies have to cover the full costs of the service.

4.2 Creating a new water culture

The mexican water authorities have a difficult challenge regarding the management of water policy. The national water policy is in fact based on a series of basic principles; most relevant are the following two:

1) Water management should be carried out according to river basins
2) Organized participation of users is a fundamental factor for achieving any objectives proposed.

First, the decision to consider the river basins and not the geographical-political boundaries comes from the fact that a river basin is a natural geographical unit that may cover several states. In effect, in a river basin rainwater precipitates, is filtered, then flows into the ocean or to closer inland basins. Second, water management policy also takes into account the participation of users, indispensable for actions taken to be successful. Nevertheless, these challenges are still not fulfilled as planned, because the water policy in Mexico has to struggle against a water culture that is difficult to change in the short-run. However, the National Water Commission and the mexican Government have recently been promoting a new-culture plan based on shared responsibility, a sense of community and water solidarity, as reported in the latest National Water Program of CONAGUA issued last in February 2008[14] The new water culture is focused on improving the "value added" of water through teaching all citizens of the economic, political and social value of water, as a strategic element of Mexico`s development. Similarly, education in topics related to the proper use and care of water will be promoted in public schools (especially in the primary and secondary schools accounting for the most significant enrollment among the lowest and middle class) through "talks" and key concepts associated with water management and conservation included in school textbooks. However, the main difficulties in pursuing such plans lies in the fact that Mexico is facing growing problems related to the over-exploitation of regions where water is scarce, the pollution of several supply sources is increasing, the illegal settlement of certain areas is highly risky given that the population is growing and the increasing social conflicts in the country that might interfere with this policy are more spread out. Therefore, it becomes necessary to consolidate this culture at multiple-level, considering the significant difference among the social classes and improving the net fiscal obligations among all users. This latter point is particular week in Mexico, especially for control of the water duties and fees for discharging wastewater.

[14] National Water Program 2007-2012, February 2008. CONAGUA, Mexico.

4.3 The New Agrarian Law (LAN)

In order to help the government to phase out these obstacles, there have been modifications of the Constitution and of the New Agrarian Law (1992) to improve the water management system. One of the key elements for managing water is measuring the volumes withdrawn to different uses with concessions. In fact, the plan is to grant concessions to individual users and to WUAs (water user associations), a prior decision of CONAGUA, the only authority that holds transfer property rights for water. The necessity to implement this policy of inter-sector trade in water rights resulted from growth in income and population statistics which generated an increase in the urban demand for water. The principle of this policy can be explained as following: since alternatives to the acquisition of new supplies of water, such as desalination, wastewater re-use and severe water conservation measures are often very expensive or not effectively applied, the urban areas have strong incentives to purchase water rights from rural areas in order to secure water supplies at a reasonable cost. On the other hand, the farmers would benefit by selling their water rights if the net present value was less than the price offered by the buyer. When water is transferred from a low valued use to a higher valued use in a market exchange, both parties are expected to benefit financially, and society gains in the form of higher valued output per unit of water inputs. Since the presence of water markets would increase farmers' value of water, the incentive to use water more efficiently would reduce environmental problems related to salinity, water-saturation and over-exploitation of the resources. In practice, the law is intended to decentralize much of the management of Mexico's irrigation districts, because by doing so it would be possible to monitor and assess the behavior of river basins and aquifers in a constant and accurate way, in real time and, most importantly, controlling those users who utilize waters irregularly by extracting more water than granted in concessions. This also would mean that under the new law, water remains national property and the allocation of water rights continues to follow an administered system, but it allows, within certain limitations, the trading of concessions on an open market. Once issued, these concessions have to be recorded in the Public Registry of Water Rights (REPDA), maintained by CONAGUA and open to the public. REPDA is in charge of registering and listing all concession holders and manages all the bureaucratic aspects related to certifying public and juridical acts of registration, extension, suspension, termination and transmission of water rights, as well as of permits for sewage waters utilization. This cooperation with CONAGUA allows the authorities to control the assigned volumes, as well as to record the information needed to grant future concessions. In addition, once guaranteed legal validity, the users who might want to defend their rights during conflicts might use concession rights as instruments. Together with these two authorities, an additional player called Irrigation District's Hydraulic Committee exists. This Committee, also created in 1992, is formed by CONAGUA`s local engineers and representatives of all the WUA`s in the districts. The Committee determines the operational rules and targets for the districts, devises an annual irrigation plan and oversees whether this plan is effectively implemented. More importantly, it plays an essential role in setting the quantity and price of traded water.

4.4 The system of the concession water-rights

In Mexico, concessions can be issued for periods ranging from 5 to 50 years and are renewable, depending on the district's needs. Along with the concession, a manual that describes regulations for O&M as well as for budgeting, cost recovery and financial administration is provided to the water user associations, which legally assumes certain responsibilities to coordinate the use of these concessions with the users. The concession does not mention a fixed volume, but its efficiency is defined as a proportion of the available storage. Based on annual allocation, the WUA makes its annual irrigation plan, and distributes water among its users. An important peculiarity of the laws lie in the definition of consumptive use and return flows that determine which fraction of the concession is tradable. In short, the associations are based on principle of welfare as opposed to being for profit. In effect, the law does not provide for third-party rights to return flows, which means that these returns, if any, are made available to users at no charge; this would reduce transaction costs of water trade. Concessions of national waters are one of the most effective tools for water management because they are a basic instrument for allocating this resource and can only be granted when water is available. Nevertheless, the effectiveness of this instrument has not been completely successful in Mexico, due to a lack of attention of the authority to inform users about their concessions. In effect, the WUAs are in general poorly informed about their rights and concessions, and this lack of efficient cooperation with REPDA could lead to unpleasant and inconvenient consequences between the WUAs, who might be unsatisfied about the assumed volume of water granted and actual volume delivered. This problem occurred in effect in 1992-93 and 1996-97 in some districts in the north of Mexico, for example in the ARLID case in the State of Guanajuato, discussed below.

4.5 The ARLID case

ARLID is located in the State of Guanajuato, central Mexico, and has a command area of 112.772 hectares, served by four dams of approximately 1700 deep tubes and wells. During the period analyzed (1982-1996) there were almost 24,000 water users, of which 55% were classified as "ejidaratios[15]" and 45% as small private farmers. The surface water for the district was provided by a system of dams with a combined storage capacity of 2140 MCM (million cubic meter); however, the actual volume available for irrigation during that period was only 880 MCM. In short, the WUA,

[15] Members of the land reform communities that were created during the Mexican revolution in the early part ofthe 20th century. Until the revision of Article 27 of the Constitution in 1992, ejido land belonged to the Mexican State

called Acambaro, received 30% less than the proportional volume accorded by the concession right. The two other WUAs, Abasolo and Corralejo, instead received 11% more. This was not the result of poor allocation by CNA but rather because of the climate conditions, which made Acambaro to require less irrigation water in that season. As a consequence, the water law claims that the WUA which is facing the water deficiency can sell some of its concessions to other WUAs which actually need more water.

In particular, there are three ways:

1) To trade the concession permanently for the entire period
2) To trade the concession for a shorter period
3) To rent the concessions for a short period.

The latter method is the most common, and the first episode of water trading took place in 1995 during the summer season between the WUAs of Acambaro and Cortazar, and of Salvatierra and Huanimaro. The price was determined together by both seller and buyer. CNA, REPDA and the Hydraulic Committee monitored the trade, acting as supervisors, reserving the sole right to act as the only faculty to argue the price-level. In particular, the authorities had to consider the opportunity costs of transporting the water between the WUAs that might have a significant effect on the price level. However, the player most controversial and determinant in water trading concessions is the weather. In effect, climate conditions might affect the water-trade between the WUAs, and that is exactly what happened for the case of the ARLID district in 1995-96. The summer season is the raining season, hence with less irrigation required, and the winter drying season is the one with most irrigation water required. At the end of the winter season, some WUAs had fully used their assigned volume of water for the entire year, but desperately needed to buy extra water to be able to deliver it, at least, to those farmers who had already paid for the next irrigation season. However, at the same time that WUA was ready to buy, an unexpected rain set in and the necessity to buy water suddenly declined. Climate change affects either the initial concession, the actual delivery and thus negotiations, which for this reason have to be very flexible. Water trade between WUAs is therefore characterized by solidarity, non-profit making behavior and mutual support in case of a water-crisis due to scarcity. Failing to do so would jeopardize their credibility among users. In addition, the stability and sustainability of the system in the long run are necessary to let users continue cooperating with CNA for a better management of the water sector.

4.6 The water-pricing system of the WUAs

The price, as well, has to be very flexible, because it has to take into account the annual inflation affecting the costs of transaction. Therefore, it may happen like in the period 1994-95 when the financial crisis started in December 1994, followed by an annual inflation rate of 50%, that the WUAs were not able to maintain the same fee level of irrigation. As a consequence, some WUAs sold their water concession rights to other WUAs at prices much lower than the price they would have received if they had sold the same volume to their own users. Different economic theories have tried to improve the "Water-Pricing System". According to Briscoe, water can be treated as an economic good where its price is set equal to its marginal cost (P=MC) and profit maximization calculated where marginal costs equal to marginal revenues (MC=MR). Briscoe claims that the perfectly competitive market with zero profit would be a possible solution. On the other hand, Perry argues that water is also a social and political good, making it difficult to simply set its price equal to its marginal cost. While Colby claims that water transfers between buyers and sellers can only be efficient "if the seller receives a price that covers any costs he has incurred in transferring the water, if the buyer expects returns from the purchase to exceed all costs, and if the buyer views a market purchase of water as an economically attractive method of obtaining water". What is certain is that because of the nature of the good "water", there are three reasons why the price-setting system can't follow strict economic mechanisms:

1) There is little competition among players, (only 11 in the district of Guanajuato, for example). As said before, the main object of water trade is not because it is lucrative but rather to "jointly manage the district". The price that is paid and the opportunity to allocate water to higher values are considered less important than the social and political aspects, in order to maintain the level of solidarity in case of any adverse conditions.
2) The trade volumes are relatively small. No players would argue for higher prices if this would disturb the relationship with other WUAs.
3) The relative abundance of water limits the development of introducing market forces in water allocation/pricing. However, this last point has several current constraints due to the crisis resulting from over-exploited aquifers, especially in the northern part of Mexico, and its relative abundance of water which prevailed some decades ago and decreased over time, putting several constraints on large parts of the command area.

Nevertheless, It has to be said that despite the system of transferring water-rights to users and that WUAs actually introduced positive factors, pushing the farmers to a more careful management of water resources and gradually reducing the subsidies to the water sector in that area, as mexican irrigation districts vary widely in terms of technical and institutional conditions and arrangements, it is hard to generalize the experience from an unique case, like the ARLID case to all districts. To this day, the rights for the use and exploitation of resources reflect more closely the water scarcity occurring in Mexico. However, the water-rights system in Mexico still has several challenges before being considered fully successful and an example for other countries facing similar problems with water scarcity.

4.7 The National Water Program (2007-2012)

In 2001 CONAGUA estimated a total of 437000 users. Thanks to REPDA, the majority of those officially registered have respected the law regarding the management of the use of water, and 97.5% of the users kept registering themselves until 2001. However, the fact some did not register has delayed and disturbed the efficiency and control of the water market by the authorities. In December 2005 over 86 irrigation-districts have been organized on a surface area of 3.5 million hectares, covering 99% of the total available irrigation-area and excluding only 3 districts. The improvement of this water-rights transferring system is possible only by better and more efficient cooperation between the authorities, CNA, REPDA and the Hydraulic Committee. With regard to instruments of order-and-control it may be said that, despite the increased visits by CNA in 2000, (4545 nationwide, more than three times of those made from 1995 to 2002), the number of users visited was only 1.2% of those registered in REPDA. The LAN of 1992 has certainly improved "monitoring activity", and the management of the water sector seems better than 20 years ago. In addition, the Government of Mexico and CONAGUA are planning to improve this situation by implementing, on a national level, Letters of Commitment to citizens for all the procedures and applications regarding water management, in order to extend the transparency of the new national water program nationwide over the period 2007-2012[16]. Moreover, the challenge of sustainable water use calls for investigating alternative in the financial system, meaning the development of "Water Banks". The installation of water banks will make it possible to have modern administration of water suited to the dynamic conditions prevailing in the water rights market, and will help to regulate a better efficient use of water thereby reversing its over-exploitation.

[16] National Water Program 2007-2012. CONAGUA, Mexico

CHAPTER 5

WATER SCARCITY PROBLEMS IN THE STATE OF MEXICO (EDOMEX): EVIDENCE IN MEXICO CITY METROPOLITAN AREA

5.1 Demographic summary

The State of Mexico is a state in the center of the country, and its capital is the city of Toluca. Mexico State is bounded to the north by the states of Hidalgo and Queretaro, to the east by Tlaxcala and Puebla, the south by Morelos and Guerrero and to the west by Michoacan. The Mexican Federal District (DF) and the capital Mexico City are not in the State of Mexico, but the capital borders to it to the west, north and east of the District. By 1993, Mexico City was officially the Federal District and capital of the United Mexican State, and it is divided in 16 boroughs and 2438 municipalities. The Mexico City Metropolitan Area (ZMCM in spanish), constituted by the Federal District, incorporates some municipalities of the State of Mexico (59) and some of the State of Hidalgo (29).

During the last twenty years, this metropolitan area has been subjected to a significant increase in the population, especially from 1990 to 2000, with a growht rate of 1.65%. Then, during the period 2000-2005 the growth rate slightly decreased to 0.7%. The ZMCM covers and area of approximately 4925 Km^2 (1484 Km^2 in Mexico City and 3441 Km^2 in the State of Mexico), 0.25% of the national area. In 2000, the population density in DF was estimated at 5799 inhab/Km^2 and in the State of Mexico at 586 inhab/Km^2; however, the expanding population, rapid and disorganized, as well as the fast industrial and commercial development, desperately called for a transformation of the area, invading what once used to be protected-area. Although the majority of industries, education, health, cultural and employment facilities are concentrated in the capital, the quality of life has decreased significantly in recent years, not only due to the increasing population density but also due to the inevitable consequences that result such as the increase in air, noise and water pollution. The latter represent in effect the most difficult challenges of the institutions responsible for providing the necessary services.

5.2 The historical development of the ZMCM

The water scarcity problems which affect the metropolitan area are strictly correlated to human and geographical development. Considering the water supply and the wastewater problems means that above all, analyzing the precarious relationship between important issues like geography, climate, urbanization, migration, economic and social development. For this reason, it is essential to provide a quick overview of the changes which occurred in the ZMCM during the last 65 years. The average growing population in the metropolitan area, including Mexico City, with its Federal District and the State of Mexico, can be summarized with the following table (tab.14). In 1940, the Federal District accounted for 1.75 million of inhabitants, of which 1,6 lived downtown. The metropolitan area then began to increase, mainly towards the north, and in ten years the population almost doubled to 2.9 million. The establishment of the National Autonomous University of Mexico (UNAM) significantly increased the prestige of Mexico City, which experienced a significant increase in inhabitants due to the affluence of students from different states of the country. As a consequence, the Government decided not to authorize any additional housing construction, and this resulted in a formal and informal disorganized urban development that characterized the future of Mexico. In 1960 the population reached almost 5 million, with a population density of 123.66 inhab/hec. This was an increase of almost 73%, with more than 58% only in the urban area, compared to 1950. Although the restriction on constructing imposed by the Government of Mexico, the population increased including the low-middle class, which result in an expansion of the number of informal settlements overall in the area. 1970 coincided with the most massive urban expansion; the population grew to 8.6 million and the number of municipalities increased to 11 which continued until 2000. In effect, during the period 1999-2000 there has been a growth of immigration from the rural areas and from the medium and small-sizes cities to the metropolitan area; the growth rate was only 0.4%, compared to the 2.9% in the State of Mexico. The last data are for 2005, when the growth rate slightly decreased for the Federal District to 0.2%; while significantly decreased overall in the State of Mexico reaching 1.2%. In 40 years the number of houses tripled, and the difference between the social classes has begun to appear much more evident over the last 10 years, especially in terms of average consumption of water per capita for a region of more than 20 million. The growing population has been a challenging task from many points of view, first of all to satisfy basic needs, like water supply and the health system. Unfortunately, the responsibilities for the water sector and sanitation have been exclusively held by different levels of governments, whose inefficiencies due to political interference and lack of management have been argued throughout the years. Mexico, as a country, have achieved a score on the HDI human development index[17] of 0.842 in 2007-2008, which

[17] HDI: UN, United Nations, calculated on the basis of data on life expectancy from UN (United Nations), 2007e. World Population Prospects 1950-2050

ranks the country 51st out of 179 countries, with a capital city that considered to be amongst the most polluted in the world.

Tab.14 Average growing population of the metropolitan area (millions)

	1950	1960	1970	1980
ZMCM	2.9	5.1	8.6	13.7
Mexico City	2.9	4.8	6.8	8.8

	1990	1995	2000	2005
ZMCM	15	16.8	21.7	22.7
Mexico City	8.2	8.4	8.6	8.7

source: CONAPO, National Council of Population,2000
INEGI, National Institute of Statistics and Geography, 2000

5.3 Water availability of the ZMCM

Water availability in the metropolitan area of Mexico depends on two main categories of sources: the local groundwater sources and interbasin-transfers, and the Cutzamala River/Lerma-Balsas systems. From 2001, the total natural average availability of water in the Valley of Mexico decreased, due to the growing over-exploitation of groundwater sources and a reduction of water supplied by the Cutzamala System (tab.15); on the other hand, the volume of water supplied had to increase as a result of the growing population in the area (tab.16). Within Mexico City, the water is distributed to users through a primary network of 1074 Km of pipelines, thanks to the 16 dams spread out in the region that have a storage capacity of 2827.90 Km^3. However, the access to water varies significantly depending on the location. Mexico City is situated more than 2000 meters above the sea level, and some communities living on the borders close to the mountains might suffer from irregular supply. In 2006, more than 5% of people living in the metropolitan area still did not have access to water (97.8% in the Federal District and 92.4% in State of Mexico having access to potable water facilities); while at a national level, 18% did not have access to the water-net (89.6%). In addition, the quality of the facilities proving water and of the water itself is often precarious; while some receive water daily from the government via pipes, many people in the poor districts, estimated to be around 13.2 million in 2008, have to buy water from private vendors at different prices, by trucks which deliver water at a specific time each week. Three boroughs suffer most the lack of water supply; Iztapalapa, with 1.820.888 inhabitants, Tlalpan, with 607.545 inhabitants and Xochimilco, 404.458 inhabitants. Here, the method of delivering water by trucks covers 30% of the population, and in some parts of

Iztapalapa, the water service is available only 10 hours per day. The unfair distribution is also reflected in terms of water consumption per capita. At a national level, water consumption per capita was estimated at 364 liters/day in 1995 in Mexico City and 230 liters/day/capita in the state of Mexico, which represents a total average daily consumption of 297 liters/day/capita. However, consumption varies significantly from borough to borough. Rich parts like Santa Fe and Lomas de Chapultepec can consume up to 600 liters/day, while the borough of Iztapalapa just 30. In Europe, the average daily consumption of water is about 150 liters per capita with an average consumption index at 3%[18]. In addition, drinking water for much of the population in ZMCM comes from 20-30 liters containers of purified water, sold commercially. This is related to the quality of water and due to the low quality of the drainage and water-pipes systems. As a matter of fact, Mexico was the second largest consumer of bottled water in the world in 2004 after Italy, with 169 liters of water per capita. The Cutzamala System, together with the Lerma-Balsas river basin and the aquifers of Valley of Mexico, represents the main sources for water supply for the metropolitan area. The Cutzamala alone provides more than the 20% of the total water supply in the State of Mexico, pumping water through pipes for over 127 km, before reaching Valley of Mexico. The aquifers of Valley of Mexico then account for a further 70% of water while the rest is transported by trucks from the Valley of Lerma (10%). The System was originally devised in 1976, in order to supply water from its rivers by gradually reducing the over-exploitation of the aquifers in the Valley of Mexico. Due to the magnitude of the project, the Government scheduled three stages of implementation. First stage was in 1982, with an assumed supply of 4 $m^3/\sec$, the second was in 1985 with 6 $m^3/\sec$ and the third one in 1993 with 9 $m^3/\sec$. However, after 2000, the supplied volume of water provided to the Federal District and to the State of Mexico have been subject of ups and downs, for the subsequent seven years. The total estimated volume supplied in 2000 for the United States of Mexico was 306707 litre/sec, then in 2005 the volume increased to 324467 and in 2006 it has been registered to have 325180 litre/sec supplied. The Cutzamala System, due to the growing population which reached almost 23 million in 2008, reduced the volume of water supplied to approximately 1 $m^3/\sec$.

In terms of investments, the total cost of the three stages estimated in 1996 was 965 million US dollars; however, if one considers the additional hydroelectric plants built during the years since the demand increased, the amount becomes 1300 million. As a consequence, a fourth stage began in 1997, with the construction of an additional dam. For years, studies have indicated that if the leakages affecting the distribution system were repaired, there would have been no need to

[18] Water consumption index is the total consumption divided by the long term freshwater resources of a country. This index falls to 1 % for some central western and accession countries, and Nordic countries. The highest consumption indexes are found in those countries where agriculture water use predominates such as Cyprus, Malta, Spain, Italy, Portugal and Greece. The average consumption of water generally increased during the 1980s, reflecting changes in number of households, household appliances and lifestyles

implement the fourth stage; this would have meant saving the additional supply of 5 $m^3/\sec$ of water assumed by the Government of Mexico.

Tab.15 Average availability of water/Administrative region, 2001-2007

		Natural average availability (Km^3/year)					
	year	2001	2002	2004	2005	2006	2007
Region XIII (Valley of Mexico)		380.5	380.3	393.4	393.4	300.9	300.8

		Natural average availability per capita (m^3/inhab/year)					
	year	2001	2002	2004	2005	2006	2007
Region XIII (Valley of Mexico)		190	182	182	192	144	143

Source: SEMARNAT. CONAGUA. Basic data on water in Mexico,2001. Mexico, DF.

Source: SEMARNAT.CONAGUA. Statistics of water 2002-2007. Mexico,DF.

Tab.16 Total amount of water supplied, 2000-2006

WATER SUPPLIED (litre/sec)				
	YEAR	2000	2005	2006
United States of Mexico		306707	324467	**325180**
Federal District		35500	35730	**35730**
State of Mexico		36520	37960	**37960**

Source:SEMARNAT.CONAGUA.Situation of the sub-sector of potable water,sewer system and drainage,2002-2006. Mexico,DF.

5.4 The over-exploitation of the aquifers

The leakages are a significant problem for the water system as discussed above. In the case of Mexico City, the deficit of water availability accounts for 3000 liters/second and the level of wastewater due to leaks throughout the entire pipe system accounts for 36.1%. The boroughs suffering most (Iztapalapa, Tlahuac and Milpa Alta) are also those where the majority of the the poor live, characterized by poor network conditions and unreliable water supply. Most of the colonies do not have drainage systems, hence the quality of water could become very unpleasant, and people object accordingly. Nevertheless, the biggest problem faced by the metropolitan area is the over-exploitation of the aquifers, which can lead to floods which can seriously damage the underground metro, the historical buildings and the drainage system. During the rainy season the aquifers are expected to refill, however, this is happening less efficiently each time due to the growing construction activity. The consequence is straight forward: the water does not filter properly into the ground and the water cloak reduces year by year. The city, which is basically built on a marsh, is slowing sink because of the empty underground caves that cannot support many parts of the city any longer. Some parts of the city, like in Iztapalala and Periferico Zona-alta, where some houses, especially those inhabited by the poor, literally sink. The annual rate of withdrawal from the aquifers (for the case of Valley of Mexico) is significantly higher than the recharge rate: 45-54 $m^3/\sec$ was extracted in 2004 but a natural recharge rate of only $20\, m^3/\sec$ was measured. At national level, it was registered that for the same area had an average recharge of 1834 $hec^3/year$ and the withdrawal rate of $4665\, hec^3/year$ in 2007. This mismatch has contributed to the lowering of the groundwater table by 1 meter per year, contributing to an increase in the land subsidence rate (10 cm/year to 40 cm/year). The average annual subsidence rate in the area of the International Airport of Mexico City (Benito Juarez airport) is 20-25 cm, while the city centre is around 10 cm. Yet in 1997, the Government of Mexico City carried out a plan[19] which outlined different types of strategies, including infrastructure, storage and transportation disposals of wastewater. These plans however also noted that, due to the huge invesment costs required, the infrastructure would also require several years to be contructed, meaning that in spite of the importance of these infrastructure as part of wastewater management strategy, this would not seem to be the only alternative available. Nevertheless, a new proposal has been put forward in 2008-2009 whereby the Federal District has been carrying out new alternatives to improve this situation of the over-exploitation of the aquifers due to innovation technologies. This include new type of concrete which will replace the old type and will be installed on the main streets in the city and should absorb the rain, helping to recharge the groundwaters more efficiently. In addition, the government of the Federal District foresees a plan to divide the city into 300 sections in order to detect leaks and the areas subject to the greatest risk of a

[19] DGCOH (1997a,1997b) : Master Plans for Drinking Water and for Sewerage for the Mexico City.

flood. Each section would be controlled in order to detect how much water flows in, how much flows out, how much is wasted, as well as pressure and other technical details.

5.5 The water pricing system in Mexico

In the ZMCM, drinking water is charged per cubic meter, and the price increases as consumption level increases. Within the metropolitan area there is no uniform price, because water consumption per capita is extremely unequally distributed and the socio-economic differences contribute to this variety. Furthermore, the water charges in the state of Mexico are still based primarily on fixed rates. (tab.17). The controversial pattern of the system of water pricing concerns the operative units. These economic units administer and handle the potable water system, sewer system and treating system. The total costs that each unit faces to provide water are divided into capital and operational costs. The capital costs reflect the investment costs for infrastructure aimed at providing these services mentioned before, while the operational costs are the variable costs of maintainance that might vary with production. In 1999, the National Institute of Statistics and Geography (INEGI) carried out a survey over the 2356 operative units in the country. According to the national plan, the average unit-cost to produce and supply water in the country was 1.95 pesos/m^3 (about 0.19 USD) and 2.55 pesos/m^3 (0.255 USD) respectively. Nevertheless, the same plan is controversial: the average net benefit at a national level for the units is negative; -0.17 pesos/m^3 (-0.017 USD), meaning that 65% of all authorities do not recover their operational costs. In particular, only 11 states get a positive gain, which is 35% of the total number in the country, and only 5 get a number higher than 1 pesos/ m^3. The state of Mexico faces a gain approximately of 0[20] pesos/m^3 and the Federal District, whose capital and operational costs represent 95% of the total cost, is the only one receiving the highest gain of 2.37 pesos/ m^3(tab.18). What can be concluded from this is that the financial result from the operative units in Mexico is not profitable but running at a loss. The average price for the operative units is 2.38 pesos/ m^3 (0.238 USD), calculated by the World Bank in 2005 as the average price obtained by dividing the total amount of invoices of all the units by the number of legal connections registered[21]. However, it is important to remember that the per unit-cost of water is only related to the amount of water supplied, not produced; since it is the volume of water supplied that is invoiced which is directly connected to the users. Ironically, the average monthly portion of the income each mexican family would be willing to pay for the supply of water is estimated at 4% in Mexico City,

[20] Yunez-Naude, A., Hilda, R., Guerrero Garcia, R. and Medellin-Azuara, J. (2008): “The Water in Mexico. Consequences of the policy in the sector”

[21] Data based on a joint study conducted by CONAGUA and the WORLD BANK in 2005: “sistema financiero del agua: Situacion del subsector agua potable, alcantarillado y sanamiento, a dicembre de 2003, Mexico, CONAGUA - the World Bank document: “Mexico, Infrastructure Public Expenditure Review (IPER)” see references

not significantly different to the rest of world, with an estimate of 3.5%. However, one of the main problems in terms of cost-recovery has been that there were, and still could be, a substantial number of illegal water connections which are not registered that cloud the real value of water consumption. In 2000, it was estimated that there were about 2.5 million water connections in the metropolitan area made up as follows: 67% domestic, 16% commercial and 17% industrial. Nevertheless, this data represents no more than 70% of the total existing connections, the rest could be illegal. Another reason lies in the fact that most houses, built informally and spread out in the area, simply do not have meters. In fact, only 49% of the legal connections are metered, and users pay only 24% of the operational, mainatenance and administrative costs.

Tab. 17 Tariff of water for urban domestic use - Federal District, 2006

Minimum (cubic meter/month)	Tariff (pesos/cubic meter)
0 to 10	1.5
Maximum (cubic meter/month)	Tariff (pesos/cubic meter)
> 1500	43.1

Source:SEMARNAT. CONAGUA.Situation of the sub-sector of potable water,sewer system and drainage, 2007 Mexico,DF

Tab. 18 Costs, Price and Benefits of the water utilities

STATE	Unit-Cost water supplied (pesos/cubic meter)	Average Price (pesos/cubic meter)	Average Benefit (pesos/cubic meter)
TOTAL	2.55	2.38	-0.17
Aguascalientes	4.12	3.96	-0.16
Baja California	6.17	5.44	-0.73
Baja California Sur	5.07	3.24	-1.83
Campeche	1.09	0.81	-0.28
Chiapas	0.98	1.22	0.24
Chihuahua	2.65	2.86	0.21
Coahuila de Zaragoza	1.80	2.83	1.03
Colima	1.74	1.22	-0.52
Districto Federal	3.08	5.45	2.37
Durango	1.46	2.49	1.03
Guanajuato	2.12	2.14	0.02
Guerrero	1.93	3.18	1.25
Hidalgo	1.23	0.92	-0.31
Jalisco	3.92	1.75	-2.17
Mexico	1.89	1.89	0.00
Michoacan de Ocampo	1.13	0.95	-0.18
Moreles	1.21	1.15	-0.06
Nayarit	0.89	1.72	0.83
Nuevo Leon	6.78	4.02	-2.76
Oaxaca	0.67	0.39	-0.28
Puebla	3.24	1.12	-2.12
Queretaro de Arteaga	4.47	3.14	-1.33
Quintana Roo	3.40	4.76	1.36
San Luis Potosi	1.77	1.95	0.18
Sinaloa	2.25	2.04	-0.21
Sonora	1.99	1.69	-0.30
Tabasco	1.20	0.34	-0.86
Tamaulipas	2.59	2.10	-0.49
Tlaxaca	0.76	0.66	-0.10
Veracruz Llave	1.38	1.42	0.04
Yucatan	1.08	0.88	-0.20
Zacatecas	2.47	1.30	-1.17

Source: INEGI,, National Institute of Statistics and Geography : Statistics of water, treatment and supply of water, 1999. Mexico. World Bank, 2005 : SFA, financial System of water, Mexico. Data based on the book of Yunez-Naude, A., Hilda, R., Guerrero Garcia, R. and Medellin-Azuara, J. (2008): "The Water in Mexico. Consequences of the policy in the sector"

CHAPTER 6

DESALINATION TECHNOLOGY : EVIDENCE IN MEXICO

6.1 Desalination market: overview

Water is a crucial natural resource for the survival and growth of life, as well as for sustaining the environment. However, the majority of water on the earth is too salty for human use, of which 97% is seawater with a salt content of more than 30000 milligrams per liter (mg/l). As a consequence, water needs to be treated in order to be considered acceptable for a cumminity water supply; in particular, water has to have a dissolved salt content below 1000 mg/l. Because of the potential unlimited availability of seawater, technology has been developed through the years to obtain feasible and cheap solutions to convert salty water to fresh water. The desalination market started in 1960`s, primarily to provide fresh water for arid,semi-arid or water-stressed areas. It then took a further two decades to become more economically affordable. As water supply tends to be more expensive and the over-exploitation of aquifers increase, the alternative to desalinated water as new source is becoming a more viable solution over time for several regions in the world. The largest market will continue to be the Persian Gulf Area, due to the combination of a growing population and an increased depletion of groundwater resources. The fastest growing market will be the Mediterranean area, including Algeria, Malta, Israel, and Spain. Dubai, which depends entirely on desalination technologies due to its geographical characteristics, is the leader and second largest consumer of potable water in the world (150 gallons/day/capita). However, there are also many parts of the world that are potential markets for desalination, like Mexico, South Asia and China. Nevertheless, these countries are still unable to maximize these technologies because, overall, their water utilities are not properly structured to enable them to undertake large financial projects. Even if improvements have been made in this direction, delays between a decision that a new desalination plant is required and raising the finance to turn it into reality are constraining the desalination market, that hinder its take-off.

6.2 Desalination technologies: costs and environmental impacts

Over the years, various desalination technologies have been developed, including most importantly membrane and thermal processes. The main membrane processes are reverse osmosis (RO) , electrodialysis (ED)[22] and nanofiltration technology (NF)[23], while the main thermal processes are the multi-stage flash evaporation (MSF), the multiple effect evaporation (ME)[24] and vapor compression (VC)[25]. The basis of all desalination processes is the conversion or part of the inlet-feed water flow into fresh water production, which has two inevitable negative impacts for the environment: First, a stream of water relatively concentrated in dissolved salts will be discharged from the plant and second, the production of concentrated brine and carbon dioxide emissions results which is associated with power generation. The MSF and RO processes dominate the market for both seawater and brackish[26] water desalination, together accounting for about 88% of the total installed capacity. In particular, the major consumers of MSF are in the Middle East and North African countries, like Saudi Arabia, United Arab Emirates, Kuwait, Lybia and Iran, where the main users are municipalities, industries and power plants; the latter designed to treat seawater. With regards to RO, the major consumers are instead scattered in the USA, Saudi Arabia, Spain, Japan and Korea. The MSF process consists of a series of stages, in which "flash" evaporation takes place from brine (salty water) flowing through the bottom of the stage, with the vapour condensing to produce water on heat transfer tubes at the top of the stage. Reverse Osmosis (RO) process is a developing technology that relies on the use of membranes that act like filters. These membranes effect a physical removal of dissolved salts by allowing water to flow through the membrane itself under a certain pressure, hence rejecting the salts into the brine stream which are discharged across the membrane surface. The difference between these two techniques relies on the energy consumption. Distillation plants (MSF) usually require an inlet seawater flow around 8 to 10 times higher than membrane processes (RO), for cooling the plant down,

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[22] ED (Electrodialysis) processes are unique compared to distillation techniques and other membrane based processes, like Reverse Osmosis. The major application of electrodialysis has historically been the desalination of brackish water or seawater as an alternative to RO for potable water production and seawater concentration for salt production.

[23] NF (nanofiltration) is a relatively recent membrane filtration process used most often in situations with low total dissolved solids water such as surface water and fresh groundwater. While it is used for the removal of contaminants from a water source, it is also commonly used for desalination and food production.

[24] ME (multiple effect evaporation) uses a specific apparatus used to ensure efficient use of heat from steam in order to evaporate water. Originally used in food production, it has become widely used in all industrial applications where large volumes of water must be evaporated, such as water desalination.

[25] VC (vapor compression) consists of the evaporation by which a blower or jet ejector is used to compress, therefore increase the pressure of the vapor produced, hence the condensation temperature increases as well. This method, like most evaporators, can make reasonably clean water from any water source, and their application is filled by Reverse Osmosis.

[26] Brackish water is the water that has more salinity than fresh water, but not as much as seawater. Technically, brackish water contains between 0.5 to 30 grams of salt per litre, more often expressed as 0.5 to 30 parts per thousand (ppt or ‰). The salt water instead has a range of 30 to 50 parts per thousand (ppt or ‰).

resulting in a smaller rise in salinity of the discharged brine. In contrast, the energy consumption of membrane plants is usually less than distillation, although the brine temperature rise is relatively lower, therefore the salinity of the discharg is greater than with distillation. The costs of water produced by desalination have dropped significantly since the beginning of the 1980`s as a result of reduction in price of equipment and power consumption, and thanks to the modernization of new systems-design and operating experiences. Today, a cost of $1\$/m^3$ for seawater desalination and $0{,}6\$/m^3$ for brackish water would be feasible and most importantly, the costs will continue to decline in the future as technologies progress; for example with nanofiltration technology. In addition, desalination costs are becoming more competitive with respect to the operation and maintainance costs and with long distance water transport systems, although this latter point is still one constraining factor for several cities. The costs to desalinate water can vary significantly depending on different variables: The size and type of plant, the source and quality of incoming feed water, the location in which the plant should be installed, the site condition, the maintenance quality, the energy costs and the plant lifetime. In general, lower feed water salinity requires less power consumption because of less chemicals to purify, while the larger is the plant, the lower are the unit costs of water produced due to the economies of scale. Moreover, lower energy costs and longer plant lifetime reduce the production cost of producing water. Two elements of these costs have to be considered; capital costs (1) and annual maintenance costs (2).

1) Capital costs includes the cost of purchasing the equipment, major and auxiliary, the cost of the land, the construction management costs and contingency costs.
2) The annual maintenance costs consist of variable costs, like energy, labour, chemicals and consumable parts.

The energy costs are dominant in the thermal processes; in regions where energy is fairly expensive, RO is a favourable choice compared to any other thermal processes due to its lower energy consumption. For MSF process, the unit costs have been gradually reduced since the inital stages of MSF technology. In particular, the cost has fallen from about 9.0 $\$/m^3$ in 1960 to $1.0\$/m^3$ in 2004, which indicates that there have been several improvements in technological performances. The average annual reduction rate of per-unit costs have been estimated at 5.3% in the last 40 years. For RO process, the technology has become more popular during the past decades due to advancing technologies and falling costs (5.0 $\$/m^3$ in 1970 to less than $1.0\$/m^3$ in 2004). In particular, the costs have been contained thanks to the development of higher salt-rejecting membranes that can efficiently operate at lower pressures, and due to the increased use of pressure recovery devices. However, RO plants are still more difficult to operate than other types of plants, hence they are often used to treat less saline water, like brackish, river and wastewater, although during the last ten years its application has also been extended to use on seawater[27]. This has hence become a competitive alternative to thermal processes in terms of pricing. In summary, the costs of desalination have fallen considerably over the last 50 years and there is no reason to believe why this trend should not continue in the future. The MSF is still the leading process in seawater desalination (followed by VC and ME processes). RO and ED are the still the most used to treat brackish, waste and river water. The per-unit cost to desalinate brackish water has fallen to about $0.6\ \$/m^3$ and particularly for seawater, RO has shown great potential to become the most economical process in the future. However, it has to be mentioned that the cost of desalination still remains higher than other alternatives for most regions of the world. A common characteristic of all commercial desalination processes is that they require an input of energy to achieve the separation of fresh water from the saline feed. In particular, energy is derived from the combustion of fossil fuels, for both MSF and for RO. As distillation plants typically require an inlet seawater flow around 8 to 10 times the fresh water production, compared with 2.3 to 3 for RO, it has to be anticipated that the former would have significantly greater ecological impacts if no appropriate measures are installed. Despite that technological progress has reduced the environmental footprint, some significant impacts remain, in particular during the operating phase of the plants. One impact is the discharge of brine, a concentrated salt solution that may contain various chemicals and can affect the coastal or marine eco-system; or in the case of inland brackish water desalination, on rivers and aquifers. The second major impact is the emission of greenhouse gases in the production of electricity and steam needed to power desalination plants. Other impacts include noise, visual disturbance (especially for small desalination plants located on the seaside), interference with public access and recreation, and possible environmental impacts that might occur during the construction phase. However, there are also positive externalities by implementing desalination. Seawater desalination can help to relieve the pressure on over-exploited coastal aquifers (a significant problem for Mexico`s tourist sector) and preventing salt intrusion that seriously damage the coastal areas. However, the effects of desalination on the environment cannot be generalized because these depend on characteristics and the sentitivity of the local marine environment. For example, future impacts from brine discharge into the Mediterranean area are expected to be relatively limited

[27] the overview of the desalination costs has been provided by IDA, International Desalination Association (2002). The total costs, calculations and estimates, were taken from the Report “IDA Worldwide Desalinate Plants Inventory Report No.17, 2002” where IDA had evaluated 442 desalinate plants using MSF processes worldwide from 1957 to 2001, and 2514 plants using RO processes worldwide since the 1970`s. The total cost data, assumed to be split up into 40% capital costs for interest and depreciation on the investments and 60% of running costs are set out by IDA, 2002. Variable for desalinate plants include country, location, total capacity, units, process, equipment, water quality, user, contract year and investment costs. Reference article: Zhou, Y.T. and Tol, Richard S.J. (2004): "Evaluating the costs of desalination and water transport". Working paper FNU – 41. United States of America

compared to the impacts in the Persian Gulf. On the other hand, there exists mitigation and preventative measures, such as the strengthening of environmental institutions and water conservation, which involve physical changes to a processing plant. The latter include optimizing the size of the construction phase, the more efficient use of design and treatment techiques to reduce damage to the marine environment, and architectural measures to reduce the visual impact, especially for the tourism sector.

6.3 Desalination technologies in the Caribbean area: Evidence in Mexico

The increase in demand for water resources in small island states in the Caribbean, mostly due to the tourism sector, has recently forced both governments and the private sector to search for new ways to increase the volume of fresh water availability. In 2006, the Caribbean Environmental Health Institute (CEHI) entered into a joint collaboration with UNESCO to create the International Hydrological Programme for Latin America and the Caribbean (IHP-LAC) to address the theme of desalination for the future[28]. The study was conducted for six countries: The Bahamas, Grenada, Santa Lucia, Mexico, the United States of America and Jamaica. Desalination is utilized in many islands of the Caribbean; some of those most noteworthy because of their history of desalination, like Antigua and Barbuda, the Bahamas and Trinidad and Tobago. The preferred desalination technologies employed are Reverse Osmosis (RO), although some Multi-stage Flash Distillation (MSF) systems are use in Antigua, the Bahamas and the British Virgin Islands. In Mexico, desalination technology is already a reality, but still it is not completely effective. Experimental work has been carried out in Mexico since 1981 but most of the projects have been realized efficiently only in the Baja California Peninsula. In effect, the Northern Mexico/USA border and the region of the Baja California Peninsula have very limited water resources and most of the aquifers in the region are over-exploited or affected by salt intrusion. The annual precipitation is 202 mm/year, much lower than the country`s average which is 752 mm/year. Moreover, due to the arid climate, the average evaporation exceeds 1800 mm/year. The region depends largely on groundwater resources, however, the average recharge levels of the aquifers is much lower than the extraction level. According to the national hydaulic plan of CONAGUA for 2001-2006[29], the recharge level for the aquifers is 1400 hm^3/year, while the total extraction is approximately 3900 hm^3/year. Of the 87 aquifers spread out in the region, 13 are over-exploited and 9 suffer from salt instrusion. In the Caribbean part, the situation is less dramatic with regards to the above aspect: the annual average precipitation (1290 mm/year) is almost double than that of the

[28] IHP-LAC: International Hydrological Programme for Latin America and the Caribbean. UNESCU, Uruguay.2006.

[29] National Hydraulic Plan. CONAGUA, 2001-2006. Mexico

country`s average precipation; in addition, its geographical position (250 meters above the sea level) and the high permeability of the soil, characterized by limestone, allow the aquifers to recharge faster than in the Baja California Peninsula (25000 hm^3/year as recharge level). Therefore, the environmental problems of the two regions are different, hence the incentives to implement desalination technologies might seem to be stronger in Baja California Peninsula. First, it has to be taken into account that the tourism sector in the Baja California Peninsula cannot be compared with the Caribbean in terms of size and number of international visitors per year. The most important destinations are in fact Cancun and Cozumel (22% of the total visitors to Mexico in 2007), while Los Cabos, as the most popular city in Baja California Peninsula, accounted for only 7% of the total number of visitors in the same year. In addition, due to the geographical position of the Peninsula, the mild weather makes this area excellent for the production of citrus fruits and grapes (Valley of Guadalupe). Second, the significant salt intrusion of the aquifers, mainly caused by the agricultural activity of the farmers who tend to use irrigation lands next to the coast, is more severe in the northern Peninsula than in the Caribbean part, limiting the economy and threatening the fragile environment. One example of experimental work using desalination technology was carried out in 1981, where a group of chemical engineers started a project whereby using heat pump assisted water purification as a means of applied for water desalination[30]. The project consisted of small-scale units designed to develop systems to operate on environmentally clean, low-grade heat energy, in order to be used in case of natural disasters, or to produce potable water for close cities at a competitive cost with Reverse Osmosis and distillation technologies. In short, the principle of heat-energy assisted water purification was similar to Vapor Compression Distillation (VC); the units had to provide a certain temperature between two tanks, one containing pure water and one with dissolved solids, in order to let the water purification process work. The project also needed to be cost-effective, in order to obtain funding for the development. In particular, it had to demonstrate the potential to produce desalinated water at a price of 1 US dollar/m^3 (0.1 cents per liter) compared with a typical cost of purified water in supermarkets of 10 to 25 cents per liter. According to the results carried out by the group, a small water purification unit was built in Mexico with a capital cost of 30000 US dollars[31]. The engineers assumed an average water consumption of 240 liters per person per day (in 1981) and showed that the capital cost could be scaled up on what is referred to as the seven tenths power law. The plant, which served a population of 450000 inhabitants, operating 8000 hours per year, with a life of 10 years, would have had an annual

[30] The project was carried out by Holland,F.A, Siqueiros,J. Santoyo,S. And E.R, Heard,C.L (1999). See article: "Water desalination using heat pumps". Energy, 25 (2000) pp. 717-729. University of Morelos (UAEM), Mexico.

[31] Santoyo-Gutierrez, S.et al.: "An experimental integrated absorption heat pump effluent purification system-Part 1". Applied Thermal Engineering 1999; 19(5):461-75

borrowing cost of 0.2 cents per liter (5% as the estimated annual discounting rate) which had not completely satisfied the parameters expected by the project of 0.1 cents per liter. More recently, in 2004 the mexican Government gave the first concession for the largest municipal desalination plant in Mexico, for Los Cabos in the State of South Baja California. The cost of this plant was estimated to be 30 million US dollars financed through different sources[32]. The plant was planned to be operative by September 2006 and to provide 200 liters/sec for 20 years. In december 2003, the CARICOM estimated that there were 203 desalinating plants reported in Mexico. Nevertheless, part of them were maintained by municipalities and did not work properly, due to lack of qualified personnel, poor service from the suppliers, administrative problems and high operating and mantainance costs. For instance, in the state of Quintana Roo, in the Caribbean part, there are some plants of Reverse Osmosis located in Xcalk close to Chetumal (Quintana Roo) which are practically abandoned (tab. 19). According to the data, the total desalination capacity of Mexico was around 79424 m^3/day (919 liters/sec). Quintana Roo (Cancun and Riviera Maya) and the Baja California South (Los Cabos) are the states where desalination plants have been implemented most, due to the emerging tourism sector. Nevertheless, it can be seen from the data above that 26% of the total plants in Mexico are currently not in operation. The most commonly used technique for water desalination in Mexico is Reverse Osmosis, used by 187 plants out of 203. In particular, 60% of all desalination plants are for the tourism sector,(hotel uses), 30% for municipal uses and 10% for industrial uses. (tab.20)

[32] The finance sources were FINFRA (Fund of investments in Infrastructure), BANOBRAS (national bank for infranstructure and public services), and the OHL-Group (desalination Company) which carried out the project.

Tab.19. National Inventory of desalination plants in Mexico (2003)

STATES	Desalinating plants	national percentage	operating YES	operating NO	installed capacity (m^3 /day)	Operation capacity (m^3 /day)
Baja California	10	4.95 %	7	3	9540	8040
Baja California South	38	18.81 %	32	6	8979	3346
Campeche	3	0.99 %	1	2	3120	750
Coahuila	7	3.47 %	2	5	78	31
Durango	24	11.88 %	9	15	650	374
Guerrero	4	1.98 %	2	2	2000	900
Nuevo Leon	2	0.99 %	2	0	325	325
Oaxaca	1	0.50 %	1	0	13478	13478
Quintana Roo	107	52.97 %	88	19	38995	23266
San Luis Potosi	1	0.50 %	1	0	60	5
Sonora	5	2.48 %	4	1	471	80
Tamaulipas	1	0.50 %	1	0	1728	363
TOTAL	**203**	**100 %**	**150**	**53**	**79424**	**50958**

Source: IHP-LAC (International Hydrological Programme for Latin America and the Caribbean), CEHI, Caribbean Environmental Health Institute, UNESCU (United Nations Educational, Scientific and Cultural Organization),Uruguay. 2006

Tab.20. Desalination plants per process and location

	Desalinating plants	RO	VC	MSF	Solar	Solar experimental
Baja California	10	3	4	1	2	0
Baja California South	38	32	3	0	2	1
Campeche	3	3	0	0	0	0
Coahuila	7	7	0	0	0	0
Durango	24	24	0	0	0	0
Guerrero	4	4	0	0	0	0
Nuevo Leon	2	2	0	0	0	0
Oaxaca	1	1	0	0	0	0
Quintana Roo	107	106	1	0	0	0
San Luis Potosi	1	1	0	0	0	0
Sonora	5	4	0	0	1	0
Tamaulipas	1	1	0	0	0	0
TOTAL	**203**	**188**	**8**	**1**	**5**	**1**

RO: Reverse Osmosis, VC: Vapor Compression, MSF: Multi-stage flash, Solar: solar experiments

6.4 Making the best use of desalination: challenges and opportunities

The ability to make best use of desalination is subject to a series of wider considerations related to the water sector. Countries that utilize desalination technologies as options to provide fresh water do so because they have judged the quality, quantity and reliability of such technologies above that which other sources cannot offer as efficiently. For some countries with weak water utilities, high water losses (30% to 50% in the case of Mexico) and poor sector policies, this would mean that the implemention of water desalination plants may not be wisely used, not as cost effective as other alternatives, and there would be a risk that substantial amounts of money would be used inefficiently, therefore not reversing the water scarcity problems as intended. The major challenge has been the significantly higher costs of producing potable water compared to traditional sources, like surface water, groundwater and rain water. In addition, these technologies have not been well understood until perhaps more recently, therefore the operation of such facilities has been left to those considered highly skilled. Difficulties have been reported such as voltage fluctuations, which constrained the production capacity, filter and membrane damage, which required great maintenance costs, and corrosion problems due to the proximity of the plants to the coast. However, it has to be considered that the relatively short time in which a Reverse Osmosis plant can be operative can also be a factor in favour of desalination, and the fact that the technology costs seem to decrease, makes desalination more affordable. In the case of Mexico, desalination has been used mostly for the tourism sector, which appears to present the greatest opportunity for utilization of desalination, thanks to the large resorts which require significant amounts of fresh water. As the water sector deregulates itself, more opportunites for private sector operators will emerge, with the chance that production costs would be reduced with benefits for the consumers. Nevertheless, desalination alone might not be able to deliver the promise to improve water supply nor solve the water scarcity issues of the country, but it should be combined with a more efficient waste-water system in order to reduce the significant amount of water losses from infrastructures and the exploitation of aquifers. This cannot be extended to every country having similar water scarcity problems, like for some states in the Arabian Gulf which succesfully took advantages of desalination technologies to control their water scarcity problems. The transport costs are another costraining element for the implemention of desalination technologies, especially for those areas far from the coast, or in high places, like New Delhi or Mexico City, exactly where there are the biggest water problems. The following data in table No. 21 estimate some sample calculations of the costs of desalinated water in some cities facing water-stress problems. Nevertheless, it has to be mentioned that most of the information about costs are held by private companies, hence the results are commercially sensitive and have to be treated with great caution[33].

[33] the literature search that discuss water transport costs refer back to Kally (1993). Kally, E and Fishelson, G. (1993): “Water and Peace, Water Resources and the Arab-Israeli Peace Process", edition Praeger publishers.

Tab.21.The cost of desalinated water to selected cities

City, country	Distance (km)	Elevation (m)	Transport (c/m^3)	Desalination (c/m^3)	Total (c/m^3)
Beijing, China	135	100	13	100	113
Delhi, India	1050	500	90	100	190
Bangkok, Thailand	30	100	7	100	107
Riyadh, Saudi Arabia	350	750	60	100	160
Harare, Zimbabwe	430	1500	104	100	204
Crateus, Brazil	240	350	33	100	133
Ramallah, Palestina	40	1000	54	100	154
Sana, Yemen	135	2500	138	100	238
Mexico City, Mexico	225	2500	144	100	244
Zaragoza, Spain	163	500	36	100	136
Phoenix, USA	280	320	34	100	134

Source: Kally,E. (1993)

The costs of desalination are assumed to be 100 million cubic meter per year (MCM/year). Transport costs are assumed to be 0.06 $ (US dollars) for 100 km horizontal transport plus 0.05 $ (US dollars) per 100 meter of vertical transportation. Distance and Elevation are taken from the Times Atlas of The World[34]._The costs of the actual desalination, here assumed to be 1 $/m^3$, are typically larger than the costs of transport. Thus, desalinated water would only really seem expensive in places that are either far from the sea and high, like Mexico City. In other places, the dominant cost would be desalination and not transport. According to the data, to deliver water to Phoenix, Zaragoza or Crateus in Brasil, the cost would be approximataly 1.3 $/m^3$. These would probably be based on competitive prices and would may fall in the future. However, getting water to New Delhi would cost 1.9 $/m^3$ and to Mexico City would cost 2.4 $/m^3$, much higher than in other cities. Therefore, it would seem to be more effective to combine strategies of wastewater re-use and desalination technologies in order to convert wastewater into high quality water and reduce water scarcity problems. Nevertheless, desalination should remain the last resort and should only be applied after having carefully considered cheaper alternatives in terms of cost-effectiveness, meaning that the marginal costs to treat wastewater should not exceed the marginal costs of using desalination techonologies. Moreover, these solutions should also consider the real local needs and economic conditions in terms of water supply and demand which are different from country to country and depend also on the current national water policy.

[34] Times Atlas of The World, 10th edition, 1999.

CONCLUSION

Based on the analysis of the objectives presented in this thesis, taking into account the research questions proposed in the introduction and information from a number of relevant academic and other sources, it is clear that the problems related to water scarcity which affect currently Mexico are complex and multi-dimensional, and the management of water resources is at present inefficient in addressing these.

1. This paper has discussed the effects and implications of some of the possible solutions to control demand and supply of water in Mexico; a country that has acted as an interesting case study example of how to tackle issues of water scarcity, where the biggest problems of this nature are seen in Mexico City. A detailed analysis of the various sources of information and statistical data mentioned above has been done and the conclusion reached from this analysis is that the water scarcity problem in Mexico is likely to remain complex in the foreseeable future, especially in the metropolitan area where the problems are amplified due to the population growtg, expected to increase even further. The main points highlighted and analysed within this paper can be outlined as follows: the negative consequences which exist for the the mexican population and for the environment due to the increasing over-exploitation of aquifers, the effects of a decoupled subsidy applied to the Tariff 09 as a possible solution to control demand and supply of water in the agricultural sector, with benefits for both the sector and the country, the inefficiencies of the national water policy with attempts to decentralize the water rights to water user associations, and lastly, the difficult application of desalination technologies to improve the water availability in the country, which appear only to benefit the tourism sector instead.

2. Accordingly, unless the current flaws in management practices are rectified, the future solutions will require significant investment costs to transport more water from distant and expensive sources, which I have indicated may not be cost-effective due to various factors discussed previously. Instead, rather to fulfill the needs of an expanding population in terms of water quantity and quality, it will be necessary to formulate and implement a long-term integrated management plan, which does not operate effectively at the moment. Hence, in this respect, the issue of water scarcity currently affecting Mexico is not only the result of technological and climate constraints, but also seems to be a matter of public policy and institutional failures instead. Despite the improvements made in terms of water policy with attempts to modify the national water law, Mexico still suffers from a lack of efficient management over the water sector. In addition, Mexico needs to improve the institutional coordination between the governments of different regions in preparing and implementing such plans mentioned above, not only to involve and more efficiently value the public, but also to increase an effective control over the water rights system across the population. Most importantly, the effects of such a change in the water policy seem to be politically feasible and might limit possible water struggles arising in the country.

3. At a national level, most of the problems seem to rely on the over-explotation of aquifers which constrain the development of the agricultural sector. As explained in the third chapter, eliminating the electricity subsidy would not seem to be an effective solution, least of all politically convenient. On the other hand, a gradual reduction of the use of water for the agricultural sector would bring benefits not only in terms of demand/supply of water for the sector, but also to the fragile environment of Mexico. The current policies on tariffs need to be restated in order to be more representative of the socio-economic status of the people living in Mexico, while water allocations for different consumers need to be systematically planned and better organized. This would mean to allow the financial system be independent of water institutions and explicitly consider access of water to the poor, perhaps using a targeted or crossed subsidy.

4. However, the situation for ZMCM regarding the management of water resources seems to be more complex and the problems which affect the capital are also linked to socio-economic expectations, regional development policies and steady increases in the population. This latter point has specifically constrained the supply of water in Mexico City, although the population growth rate has declined during the twenty first century. Nevertheless, as highlighted in chapter five, the situation in the metropolitan area is worse than in the rest of the country. The area is heavily urbanized, hence subject to groundwater contamination because of the absence of an efficient sewage network, which has not been economically constructed due to the presence of volcanic rocks (basalt rocks). In addition, the risks of aquifer contamination is worsened due to inadequate wastewater treatment facilities and leakages from the sewage system which directly flow into groundwater resources, but also due to housing complexes not properly built which all contribute to increased water pollution in the city. Based on the statistical predictions analysed, we can assume that the current approach to the management of water supply and demand in the metropolitan area is neither efficient and equitable, nor sustainable.

5. On the other hand, I have attempted to describe and evaluate the situation for those states which base their economy on income generated from the tourism sector, which appear to have an additional solution to control their water problems in the future in comparison to the rest of the country. Nevertheless, the tourism sector in the Baja California Peninsula seems to derive more advantages from desalination technologies compared to the Caribbean part, although the increased use of such technologies for the tourism sector appears to be inevitable in the latter as well. In future, further research and development in the water scarcity agenda are needed, but there are no doubts that the existing and proposed practices for water management in Mexico could potentially become more feasible. What I can claim is that a policy focusing exclusively on the water sector to solve water scarcity is unlikely to be successful unless considered in tandem with simultaneous balance between urban development, natural resources, the environment and the health system. I have attempted to show that Mexico needs to find viable, cost-effective solutions which are suitable to the unique characteristics of the country; geographically, economically and otherwise. Although there are no one-

size-fits-all solutions in the mexican case nor an overwhelmingly unique policy to tackle this problem, but as outlined, there are different methods to be evaluated, one cannot evaluate any policy or mechanism in isolation. Thus, considering the benefits and disadvantages of all possible alternatives is essential in order to effectively address the consequences of water scarcity in Mexico.

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APPENDIX

Tab.12 Estimated variables (Model 1)

Variable	Robust Coefficient	Standard error	t	P>t	95% CI interval	
Shadow WaterPrice	-1902.01	307.71	-6.18	0.00	-2505.75	-1298.27
Temperature	-1.70	4.070	-0.42	0.68	-9.68	6.28
Marginalization	-38.17	10.89	-3.50	0.00	-59.54	-16.80
granted volume	0.00	0.00	0.69	0.49	0.00	0.00
agricultural surface	4.98	0.52	9.50	0.00	3.95	6.01
users	2.26	1.27	1.78	0.07	-0.24	4.76
Dichotomic Type techn.1	125.99	23.97	5.26	0.00	78.97	173.01
Dichotomic Type techn.2	97.12	75.11	1.29	0.20	-50.24	244.48
Dichotomic Type of cultivation (fruit)	52.33	39.14	1.34	0.18	-24.46	129.13
Dichotomic Type of cultivation (vegetables)	-8.22	44.17	-0.19	0.85	-94.88	78.43
Dichotomic fields	93.86	38.33	2.45	0.00	18.65	169.07
Distance	-0.29	0.15	-1.95	0.05	-0.59	0.00
Precipitation	-0.02	0.04	-0.63	0.53	-0.09	0.05
Constant	244.78	95.29	2.57	0.01	57.81	431.74

R^2=0.39

Source: Linear model based on the Survey made by College of Postgraduated, 2002-2003.

CFE, Federal Commission of Electricity, 2002-2003. Mexico

Tab.13 Estimated variables (Model 2)

Variable	Robust Coefficient	Standard error	T	P>t	95% CI interval	
Ln (Shadow Water Price)	**-0.358**	0.037	-9.800	0.000	-0.403	-0.287
Temperature	0.009	0.006	1.500	0.133	-0.003	0.020
Marginalization	-0.009	0.030	-3.040	0.000	0.148	-0.032
granted volume	0.000	0.000	1.210	0.300	0.000	0.000
agricultural surface	0.012	0.001	9.860	0.000	0.009	0.014
users	0.002	0.001	1.340	0.090	-0.001	0.004
Type techn.1	0.033	0.053	6.330	0.000	0.230	0.437
Type techn.2	-0.182	0.160	-1.140	0.200	-0.496	0.132
Type of cultivation (fruit)	0.092	0.072	1.290	0.197	-0.048	0.232
Type of cultivation (vegetables)	0.010	0.089	0.120	0.907	-0.163	0.184
fields	0.187	0.062	2.980	0.003	0.063	0.310
Distance	0.001	0.000	3.950	0.000	0.001	0.002
Precipitation	0.000	0.000	-1.730	0.800	0.000	0.000
Constant	4.192	0.160	26.200	0.000	3.878	4.506

R^2=0.53

Source: Linear model based on the Survey made by College of Postgraduated, 2002-2003.

CFE, Federal Commission of Electricity, 2002-2003. Mexico